DYAL SINGH PUBLIC LIBRARY
ROUSE AVENUE, NEW DELHI-1

Class No. 583
Book No M565A
Accession No. 7903

DYAL SINGH PUBLIC LIBRARY
ROUSE AVENUE, NEW DELHI-1.
Cl. No. 583 M565A V.2
Ac. No. 7903 Date of release for loan
This book should be returned on or before the date last stamped below. An overdue charge of 0.6 P. will be charged for each day the book is kept overtime.

KEY TO TISSUES

STEMS AND PETIOLES

SCLERENCHYMA ■

▥ —**XYLEM**

CHLORENCHYMA ┆

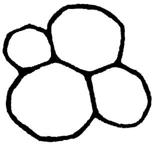
▩ **COLLENCHYMA**

CORK— ⋀

░ —**PHLOEM**

WOOD

VESSELS



RAYS— ▨

▧ —**PARENCHYMA**

SEPTATE FIBRES ≋

░ —**PHLOEM**

TRACHEIDS— △

■ **SCLERENCHYMA**

The above types of shading have been used for the tissues in the drawings which have been specially prepared for this book. They do not apply to drawings where an author's name is given. Septate fibres not shaded except where forming patches in the ground-tissue of the wood. Transverse sections of Wood × 50, Rays × 90.

ANATOMY OF THE
DICOTYLEDONS

ANATOMY OF THE DICOTYLEDONS

LEAVES, STEM, AND WOOD
IN RELATION TO TAXONOMY
WITH NOTES ON ECONOMIC USES

BY
C. R. METCALFE
M.A., PH.D.
JODRELL LABORATORY, ROYAL BOTANIC GARDENS, KEW
AND
L. CHALK
M.A., D.PHIL.
IMPERIAL FORESTRY INSTITUTE, OXFORD

WITH THE ASSISTANCE OF
M. M. CHATTAWAY
C. L. HARE
F. R. RICHARDSON
E. M. SLATTER

VOLUME II

OXFORD
AT THE CLARENDON PRESS

Oxford University Press, Amen House, London E.C.4
GLASGOW NEW YORK TORONTO MELBOURNE WELLINGTON
BOMBAY CALCUTTA MADRAS KARACHI
CAPE TOWN IBADAN NAIROBI ACCRA SINGAPORE

FIRST EDITION 1950
REPRINTED LITHOGRAPHICALLY IN GREAT BRITAIN
AT THE UNIVERSITY PRESS, OXFORD
BY CHARLES BATEY, PRINTER TO THE UNIVERSITY
FROM CORRECTED SHEETS OF FIRST EDITION
1957

CONTENTS

KEY TO TISSUES IN THE DRAWINGS . . . *front endpaper*

DESCRIPTIONS OF THE FAMILIES

157. ARALIACEAE—263. CERATOPHYLLACEAE 725

LISTS OF FAMILIES IN WHICH CERTAIN DIAGNOSTIC FEATURES OCCUR 1326

APPENDIX I

DISTRIBUTION OF CELL DIMENSIONS, ETC., IN DICOTYLEDONOUS WOODS 1360

BIBLIOGRAPHY 1363

INDEX 1459

157. ARALIACEAE

(FIG. 168 on p. 726; FIG. 169 on p. 728; FIG. 170 on p. 732)

SUMMARY

(i) GENERAL

A predominantly woody family, chiefly from the tropics, although the ivy (*Hedera helix* Linn.) is a familiar member of the family from temperate regions. The family includes species which climb by means of adventitious roots. Since Solereder's work was published, Viguier (2335) has made a fairly extensive and detailed examination of the family, thereby extending his earlier work which was cited by Solereder. The leaf is usually dorsiventral, but tends to have a homogeneous or centric structure in some species. **Hairs** are not very numerous in some species. Where present they include shaggy, 2-armed, tufted, stellate, and peltate types. **Spines** occur in a few species. The **stomata,** which in the leaf are mostly confined to the lower surface, are frequently rubiaceous, although this is by no means universal. **Hypoderm** is sometimes present, especially towards the upper surface of the leaf, but is often restricted to certain parts of the lamina. The **mesophyll** frequently includes a palisade tissue of rather elongated cells, some of which are arm-cells. In most species the principal vascular bundles of the **petiole** are arranged in a ring, although an arc of bundles occurs occasionally. The individual petiolar vascular strands are distinct in most species, but in others are united by or embedded in sclerenchymatous elements. **Medullary bundles** also occur in the petiole and/or stem of quite a number of genera, where their size and more exact distribution provide characters of diagnostic value. The main vascular bundles of the stem, like those of the petiole, are arranged in a ring. **Secretory canals** are very common, and occur in the cortex, phloem, and pith, sometimes being present in more than one of these tissues in an individual species. Canals occur in both leaf and axis, and, in the leaf, are most readily visible in the petiole. **Secretory cavities,** which, in transverse sections, resemble the canals, have been recorded in a few instances. Secretory cells are unknown.

(ii) WOOD

Vessels commonly in short radial multiples and clusters, sometimes with longer radial multiples or with a tangential or ulmiform arrangement, often ring-porous, sometimes with spiral thickening, perforation plates usually simple, occasionally with a few scalariform plates or with scalariform plates predominating; intervascular pitting commonly scalariform or opposite, sometimes alternate, pits to parenchyma often larger; members of medium length to moderately long. **Parenchyma** paratracheal only, often extremely sparse. **Rays** usually up to 4–6 cells wide and commonly more than 1 mm. high, heterogeneous. **Fibres** with simple pits, commonly septate, of medium length to moderately short. **Intercellular canals** present in the rays of several genera.

LEAF

Nearly always dorsiventral, but tending to have a homogeneous or centric structure in certain species. Lamina exhibiting a considerable range in thickness in different species, e.g. ranging from 130 to 700 μ in *Schefflera* according to Viguier (2335). Often glabrous. **Hairs** (Fig. 168) include the following types. (i) Shaggy, of variable length, with pointed or blunt ends and multiseriate bases in species of *Acanthopanax*, *Aralia* (Fig. 168 A), *Fatsia*, *Kalopanax*, *Panax*, *Pentapanax*, *Stilbocarpa*. (ii) Two-armed with uniseriate stalks composed of short cells in *Didymopanax* and *Sciadophyllum*. (iii) Tufted or stellate with uniseriate or multiseriate rays in species of *Astrotricha*, *Fatsia*, *Hedera* (Fig. 168 B–C), *Oreopanax*. (iv) Tufted, but composed of unicellular portions, recorded in the floral region of *Brassaia* and *Schefflera*. (v) Peltate in *Hedera*, and sometimes in *Oreopanax* (yellow coloured). (vi) Uniseriate, occasionally slightly branched, in *Cussonia* and *Kalopanax*.

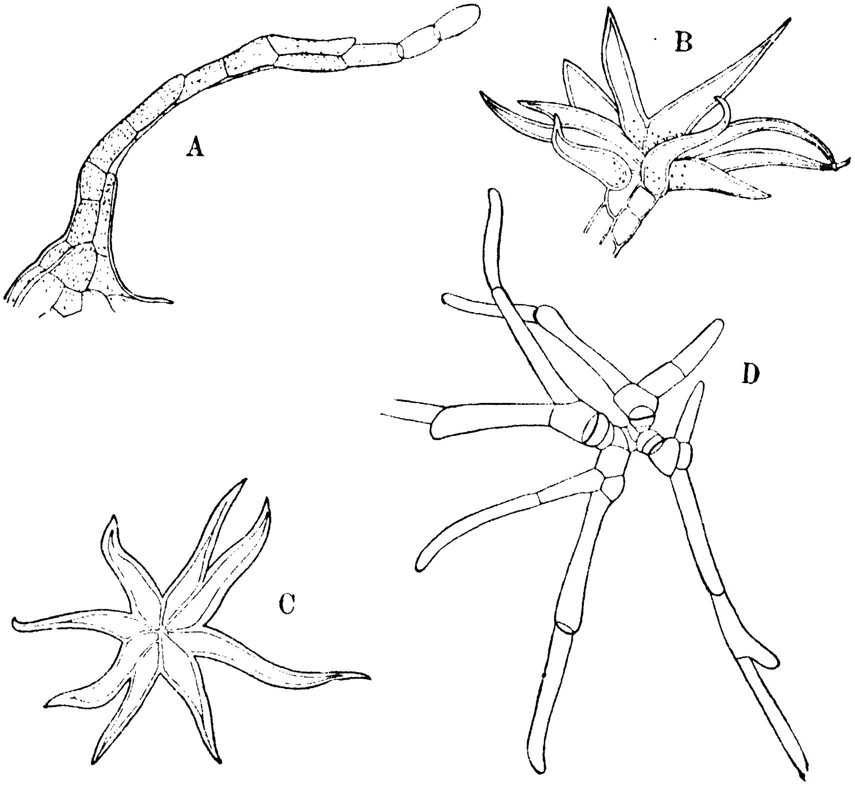


FIG. 168. *ARALIACEAE*
A, Shaggy hair of *Aralia californica* S. Wats. B, C, *Hedera helix* L. (B) Tufted hair and (C) small scale-like trichome. D, Star-like trichome of *Trevesia palmata* Vis.—By Solereder.

Cork warts occur on the petiole of *Tetrapanax papyrifer* (Hook.) K. Koch and other species. **Green spots** on the petioles and veins of *Meryta* are due to local interruption of the sub-epidermal collenchyma by cells with green contents. **Swellings** on the larger veins of *Meryta* and *Strobilopanax* consist of aqueous tissue.

Epidermis affording characters of specific diagnostic value, such as the varying thickness of the outer and lateral cell walls and the nature of the cuticle. Lower epidermis with short or long papillae, the latter sometimes provided with coronulate apices, or united together by cuticular ridges standing out from the surface of the leaf in species of *Aralia* and a few of *Pentapanax* and *Polyscias*. **Stomata** usually confined to the lower surface, but a few sometimes occur on the upper side as well in a few species of *Aralia* (e.g. *A. humilis* Cav.), *Gastonia*, *Tetrapanax*. Lower surface composed wholly of the very numerous stomata and their accompanying subsidiary cells in species of *Macropanax*, *Schefflera*, *Tupidanthus*. Stomata rubiaceous in some species of *Acanthopanax*, *Aralia*, *Astrotricha*, *Cheirodendron*, *Didymopanax*, *Echinopanax*, *Eremopanax*, *Fatsia*, *Gastonia*, *Mackinlaya*, *Nothopanax*. **Hypoderm,** exhibiting various degrees of differentiation, recorded, especially towards the upper surface of the leaf, in species of *Apiopetalum*, *Arthrophyllum*, *Cheirodendron*, *Cussonia*, *Delarbrea*, *Dendropanax*, *Didymopanax*, *Dizygotheca*, *Eremopanax*, *Fatsia*, *Gastonia*, *Mackinlaya*, *Meryta*, *Myodocarpus*, *Nothopanax*, *Oreopanax*, *Panax*, *Pentapanax*, *Polyscias*, *Pterotropia*, *Reynoldsia*, *Schefflera*, *Sciadophyllum*, *Tetrapanax*, *Tetraplasandra*, *Tupidanthus*.

Mesophyll frequently including 1 layer of tall palisade cells, e.g. in many species of *Aralia*. Two layers of palisade recorded by Viguier (2335) in '*Aralia pubescens*', and 2–3 layers in *Schefflera*. Palisade tissue absent from *Aralia quinquefolia* Decne. et Planch., according to Holm (1071). Arm-palisade cells recorded by Solereder in species of *Acanthopanax* (present in all of the species examined by Kano, 1217), *Cussonia*, *Dendropanax*, *Pseudopanax*.

Vascular bundles of the **veins** accompanied by sclerenchyma in some species but not in others.

Petiole (Fig. 169 A–G and I), usually containing a ring, or occasionally (*Acanthopanax* (Fig. 169 B), *Apiopetalum*, *Panax* (Fig. 169 A), and *Pseudopanax* (pro parte)) a crescent of vascular bundles, the individual strands either distinct from one another or united by an inner or outer ring of sclerenchymatous fibres; sometimes embedded in a ring of lignified parenchyma (e.g. in *Tupidanthus*). Petiolar medullary bundles, varying in number and arrangement, provide a character of considerable value for the identification of species.

The following particulars recorded by Solereder give some indication of the more exact distribution of the medullary bundles, but there is considerable variation within each of the categories described. (A) Solitary medullary bundles in *Anomopanax*, *Pseudosciadium*, *Pterotropia* (sometimes 3 bundles). (B) Arranged in a ring, individual bundles inversely orientated, in *Aralia* (rachis of most species), *Arthrophyllum*, *Dendropanax* (pro parte), *Heteropanax*, *Kissodendron*, *Oreopanax*, *Pentapanax*, *Schefflera* (pro parte—sometimes with 2 rings). (C) Arranged in a ring, bundles normally orientated, in *Cussonia*, *Dizygotheca*, *Gamblea*, *Plerandra*. (D) Irregularly distributed, sometimes inversely orientated, in *Apiopetalum*, *Boerlagiodendron*, *Brassaiopsis*, *Cuphocarpus*, *Dizygotheca* (Fig. 169 I), *Eremopanax*, *Gastonia*, *Mackinlaya*, *Meryta*, *Myodocarpus*, *Polyscias*, *Schefflera* (pro parte), *Strobilopanax*, *Tetrapanax*, *Tetraplasandra*, *Tieghemopanax*, *Trevesia*, *Tupidanthus*. (E) A few more or less coalescent bundles in *Didymopanax*. (F) A few normally

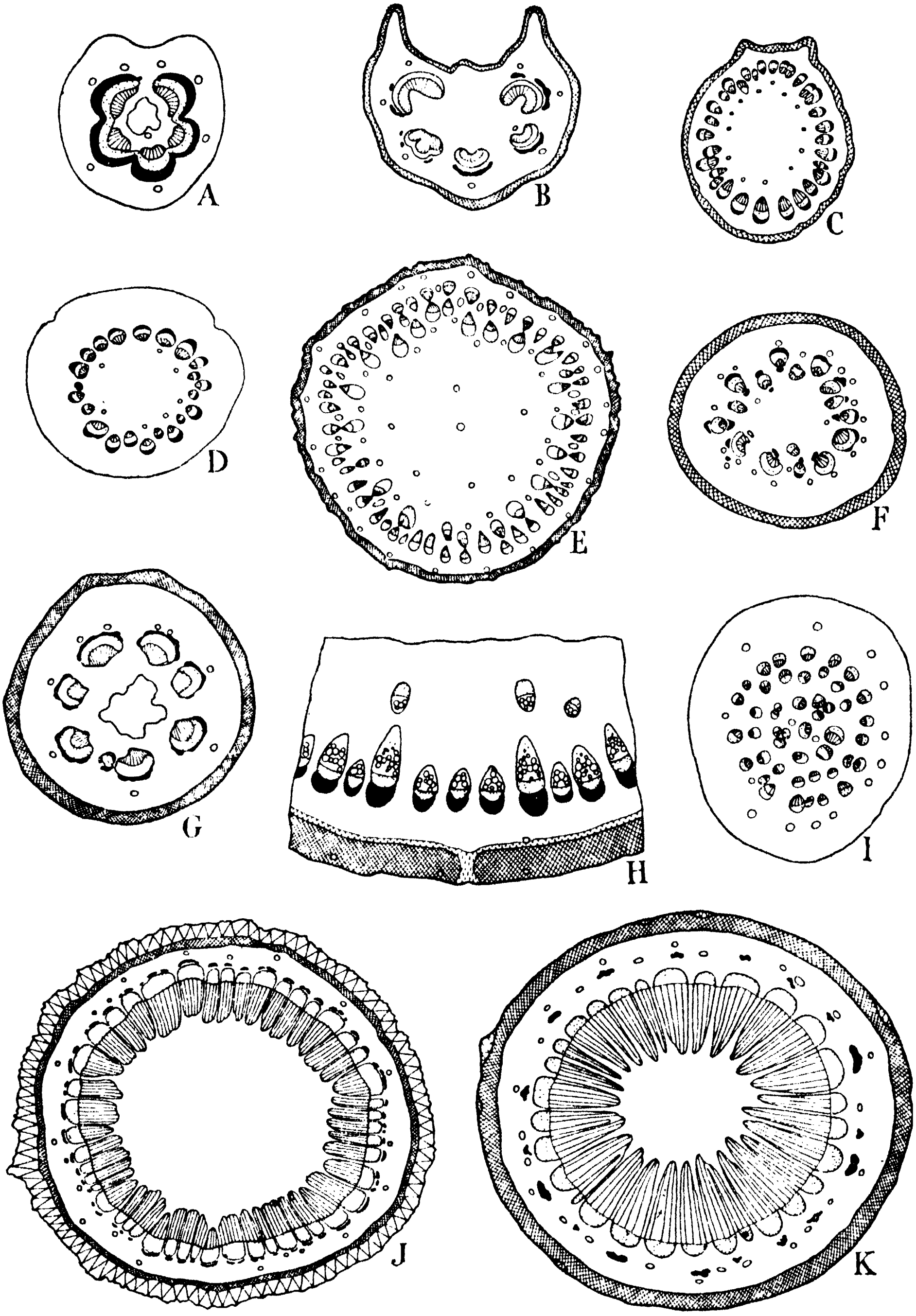


Fig. 169. *ARALIACEAE*

A, *Panax davidii* Franch. Petiole × 18. B, *Acanthopanax pentaphyllus* S. et Z. Petiole × 18. C, *Polyscias filicifolia* L. H. Bailey. Petiole × 12. D, *Fatsia japonica* Decne. et Planch. Petiole × 13. E, *Aralia chinensis* Linn. Petiole × 8. F, *X Fatshedera lizei* Guillaumin. Petiole × 13. G, *Hedera helix* Linn. Petiole × 5. H, *Aralia racemosa* Linn. Stem × 15. I, '*Dizygotheca veitchii*'. Petiole × 13. J, *Acanthopanax pentaphyllus* S. et Z. Stem × 15. K, *Panax davidii* Franch. Stem × 13.

Small, unshaded circles represent secretory canals.

orientated bundles in *Pseudopanax* and *Sciadopanax*. (G) Medullary bundles absent from the petiole of at least certain species of *Acanthopanax*, *Aralia*, *Astrotricha*, *Bonnierella*, *Cephalaralia*, *Cheirodendron*, *Delarbrea*, *Dendropanax* (pro parte), *Echinopanax*, *Fatsia*, *Hedera* (Fig. 169 G), *Macropanax*, *Nothopanax*, *Oreopanax*, *Panax*, *Pseudopanax*, *Stilbocarpa*.

The structure, arrangement, and course of the vascular bundles in *Schefflera venulosa* Harms. (syn. *Heptapleurum venulosum* Seem) have been described by Joshi (1195). The bundles in the petiole of this species, which are arranged in 2 rings, all arise from separate procambial strands. Although the bundles of the inner ring are inversely orientated throughout most of the length of the petiole, they twist through an angle of 180° at the proximal end, and thus appear to be normally orientated in transverse sections through the base of the petiole. The foliar bundles open out on passing into the stem and appear as cortical bundles. The individual foliar bundles join those of the stem at different levels so that no single leaf gap is formed. Joshi discusses these facts in relation to Worsdell's views concerning the origin of medullary bundles, and concludes, unlike Worsdell, that the medullary strands are 'new formations, rather than "relics"'.

Crystals mostly clustered, occurring in the mesophyll and in the ground tissue of the veins. Solitary crystals recorded by Solereder in *Acanthopanax*, *Arthrophyllum*, *Brassaiopsis*, *Eremopanax*, *Heptapleurum*, *Kalopanax*, and crystal-sand in the mesophyll of *Apiopetalum*, *Boerlagiodendron*, *Motherwellia*, *Tetraplasandra*. **Secretory canals** (see also 'Stem' on p. 731) present in the petiole and accompanying at least the larger veins in nearly all of the investigated species of *Acanthopanax*, *Anomopanax*, *Arthrophyllum*, *Cheirodendron*, *Cuphocarpus*, *Cussonia*, *Delarbrea*, *Didymopanax* (pro parte), *Dizygotheca* (in concentric circles), *Eremopanax*, *Fatshedera*, *Fatsia*, *Gastonia*, *Hedera*, *Heteropanax* (rachis), *Kissodendron*, *Mackinlaya*, *Macropanax*, *Meryta*, *Myodocarpus*, *Nothopanax*, *Oreopanax* (pro parte), *Pentapanax*, *Plerandra*, *Polyscias*, *Pseudosciadium*, *Pterotropia*, *Schefflera* (pro parte), *Sciadopanax*, *Tetrapanax*, *Tetraplasandra*, *Tieghemopanax*, *Trevesia* (pro parte), *Tupidanthus*. Canals often extending into the finer branches except in a few species in *Acanthopanax*, *Aralia*, *Cussonia*, *Panax*, *Pentapanax*. Secretory canals not known to occur in the leaf of a few species of *Polyscias* and *Pseudopanax*. Diameter of the canals stated by Solereder to be valuable for the identification of species. **Secretory cavities,** resembling the canals in having a lining of epithelium, stated to be characteristic of *Dendropanax*; usually appearing as transparent dots. Smaller cavities of the same nature recorded in species of *Cussonia*, *Eremopanax*, *Heteropanax*, *Kissodendron*, *Pseudosciadium*.

Axis

Stem (Fig. 169 H, J, K)

Epidermis said to contain chloroplasts, in spite of the absence of stomata, in species of *Acanthopanax* examined by Kano (1217). Young stem of all species examined at Kew at first with a continuous peripheral zone of collenchyma, but cork arises in older material. **Spines** of *Aralia spinosa* Linn. described by Davies (550) as consisting of small cortical and epidermal cells all hardened by lignification. **Cork** usually arising in the epidermis or outer part of the cortex; component cells often thin-walled, but at least some of the cells recorded by Solereder as having thickened tangential walls in species of *Cussonia*, *Dendropanax*, *Oreopanax*, and *Schefflera* (confirmed for the last genus excluding *S. abyssinica* (Hochst.) Harms. and *S. volkensii* Harms. by Viguier (2335)), and including thick-walled sclereids in species of *Oreopanax* and *Polyscias*. Cork composed of tabular, flattened cells with slightly lignified walls in *Aralia nudicaulis* Linn. according to Viguier (2335). Cork mainly thin-walled, but bounded internally by thickened cells in *Dizygotheca*. Primary **cortex,** apart from the peripheral collenchyma, in species examined at Kew, composed of very thin-walled cells, usually devoid of solid contents, but starch noted in the few species of *Acanthopanax*, *Aralia*, and *Fatshedera* examined. Stone cells recorded by Solereder as sometimes present in the primary cortex and phelloderm. Cortex mainly composed of cells with fairly thick walls in *Dizygotheca*. **Pericycle** seldom containing very much sclerenchyma; devoid of fibres in *Aralia* (pro parte), including arcs of fibres in *Aralia* (pro parte) and *Dizygotheca*; strands of fibres in *Acanthopanax* (Viguier 2335); including large or small strands of fibres in different species of *Schefflera*. Strands of pericyclic fibres observed at Kew in the species of *Acanthopanax*, *Aralia*, *Dizygotheca*, *Hedera*, and *Nothopanax* available for examination. Pericyclic fibres more fully developed in bushes than in climbing specimens of *Hedera helix* Linn., according to Bowman (250).

Vascular bundles usually separated by rather wide rays in young stems, but appearing to form a more or less continuous cylinder when more mature. Vessels mostly with simple perforations; scalariform plates occasional. See 'Wood'. **Pith.** Perimedullary region composed of a ring or strands of fibres in some species of *Schefflera* according to Viguier (2335); peripheral part of the pith in *Acanthopanax* described by the same author as consisting of lignified cells (not fibres) and of chambered fibres by Kano (1217). Central part of the pith consisting wholly of cellulose cells in some species of *Schefflera*, but lignified in other species of the same genus. Pith, in young stems of *Dizygotheca* examined by Viguier, consisting partly of cells with thin cellulose walls intermingled with a network of similar but lignified cells. Small fibrous strands, with particularly minute elements at the centre of each strand, also observed in the pith in this genus, especially in *D. apioidea* Harms. Fibrous strands less numerous or replaced by secretory canals in other species of *Dizygotheca* examined by Viguier. Small reduced bundles noted at Kew throughout the pith of '*D. veitchii*'.

Medullary and less frequent **cortical** bundles occur widely, their distribution being of value in the identification of species rather than genera. The following particulars concerning the distribution of medullary and cortical bundles have been recorded by Solereder and by Viguier (2335). (A) A single ring of normally orientated bundles in species of *Acanthopanax*, *Aralia*, *Astrotricha*, *Cheirodendron*, *Dendropanax*, *Didymopanax*, *Fatsia*, *Hedera*, *Horsfieldia*, *Kalopanax*, *Mackinlaya*, *Macropanax*, *Motherwellia*, *Nothopanax*, *Panax*, *Polyscias*, *Porospermum*, *Pseudopanax*, *Pseudosciadium*, *Schefflera*, *Tetraplasandra*. (B) A ring of normally orientated bundles accompanied by another circle of inversely orientated medullary strands in species of *Aralia* (noted at Kew in *Aralia racemosa* L.), *Arthrophyllum*, *Eremopanax*. (C) A ring of normal bundles accompanied by another circle of normally orientated medullary strands in species of *Arthrophyllum*, *Cussonia*. (D) A ring of normal bundles accompanied by a second in the periphery of the pith, together with scattered, variously orientated bundles at the centre of the pith in species of *Aralia*, *Didymopanax*, *Kissodendron*. (E) A ring of normal bundles accompanied by scattered strands in the pith in species of *Meryta*, *Plerandra*, *Polyscias*, *Trevesia*. (F) A ring of normal bundles accompanied by others in the cortex in species of *Apiopetalum*, *Brassaiopsis*, *Cussonia*, *Delarbrea*, *Heteropanax*, *Myodocarpus*, *Oreopanax*, *Schefflera*. (G) A normal ring of bundles accompanied by both cortical and medullary strands in species of *Aralia*, *Boerlagiodendron*, *Brassaiopsis*, *Tupidanthus*.

Schizogenous **secretory canals** (see 'Leaf' on p. 729) containing oily, resinous, gummy, and occasionally milky contents, universally present; usually occurring in the primary cortex, phloem, and pith; their more exact distribution valuable in the identification of species, and to some extent for genera.

Secretory canals, according to Viguier (2335), present in the phloem but absent from the pith of *Acanthopanax*; present in the cortex and phloem of some and in the pith of most species of *Schefflera*; in the cortex and pericycle of *Dizygotheca*; present in the cortex of all of the genera examined at Kew; observed also in the phloem of a few species of *Acanthopanax*, *Aralia*, and *Hedera*, and in the pith of species of *Acanthopanax*, *Aralia*, *Dizygotheca*, *Fatshedera*, and *Hedera*. Secretory cells absent. **Crystals** (see 'Leaf' on p. 729) very common; mostly clustered, but solitary prisms also occur, e.g. in the phloem of *Dizygotheca*.

WOOD (Fig. 170)

Vessels very small to medium-sized; (mean tangential diameter ranging from about 30 to 120 μ); in short radial pore multiples and in clusters, sometimes in radial groups of 4 or more; with a tangential pattern in *Fatsia*, *Pseudopanax*, and *Textoria*, 'ulmiform' in *Acanthopanax*, *Aralia*, and *Kalopanax* (Fig. 170 F); about 4–25 per sq. mm. in the diffuse-porous species without any definite pattern, very numerous in *Hedera*, *Kalopanax*, and *Pseudopanax*; ring-porous in *Acanthopanax*, *Agalma*, *Aralia*, *Dendropanax*, *Gamblea*, *Hedera*, *Heptapleurum* (1851), *Kalopanax*, *Polyscias*, *Pseudopanax*, and *Textoria*; spiral thickening present in *Agalma*, *Aralia*, *Astrotricha* (1851), *Hedera*, *Heptapleurum* (1851), *Nothopanax* (1851), and *Oreopanax* (1851). Perforations usually simple; scalariform plates with few bars present in *Brassaia*, *Cheirodendron*, *Dendropanax*, *Didymopanax* (1894, 2430), *Fatsia* (2158), *Heptapleurum* (1154), *Kalopanax*, *Macropanax*, *Polyscias*, *Pseudopanax*, *Pterotropia*, *Schefflera* (1334), *Tetraplasandra* (F. B. H. Brown, 282, gives perforations as simple only in *T. waimeae* Wawra), and *Trevesia*; scalariform plates predominating in *Agalma*, *Aralidium*, *Boerlagiodendron*, *Cussonia*, *Dendropanax*, *Dizygotheca*, *Harmsiopanax*, *Heteropanax*, *Horsfieldia* (1154), *Meryta*, and *Osmioxylon* (1206). Intervascular pitting commonly scalariform or opposite; alternate in *Acanthopanax*, *Agalma*, *Aralia*, *Fatsia*, *Gamblea*, *Hedera*, *Heptapleurum*, *Kalopanax*, *Polyscias*, *Pseudopanax*, *Schefflera*, *Sciadodendron*, *Tetraplasandra*, *Textoria*, and *Tieghemopanax*; pits to ray cells often larger than the intervascular pitting, irregular, with very narrow borders, or simple. According to Bailey (78), the sieve-like structures described by Jönssen are not vestured pits. Tyloses sometimes present. Mean vessel member length 0·4–1·3 mm. **Parenchyma** paratracheal only, often extremely sparse. Strands usually up to 4 or 8 cells. **Rays** up to 3–15 cells wide, usually 4–6 cells, up to 8 or more in

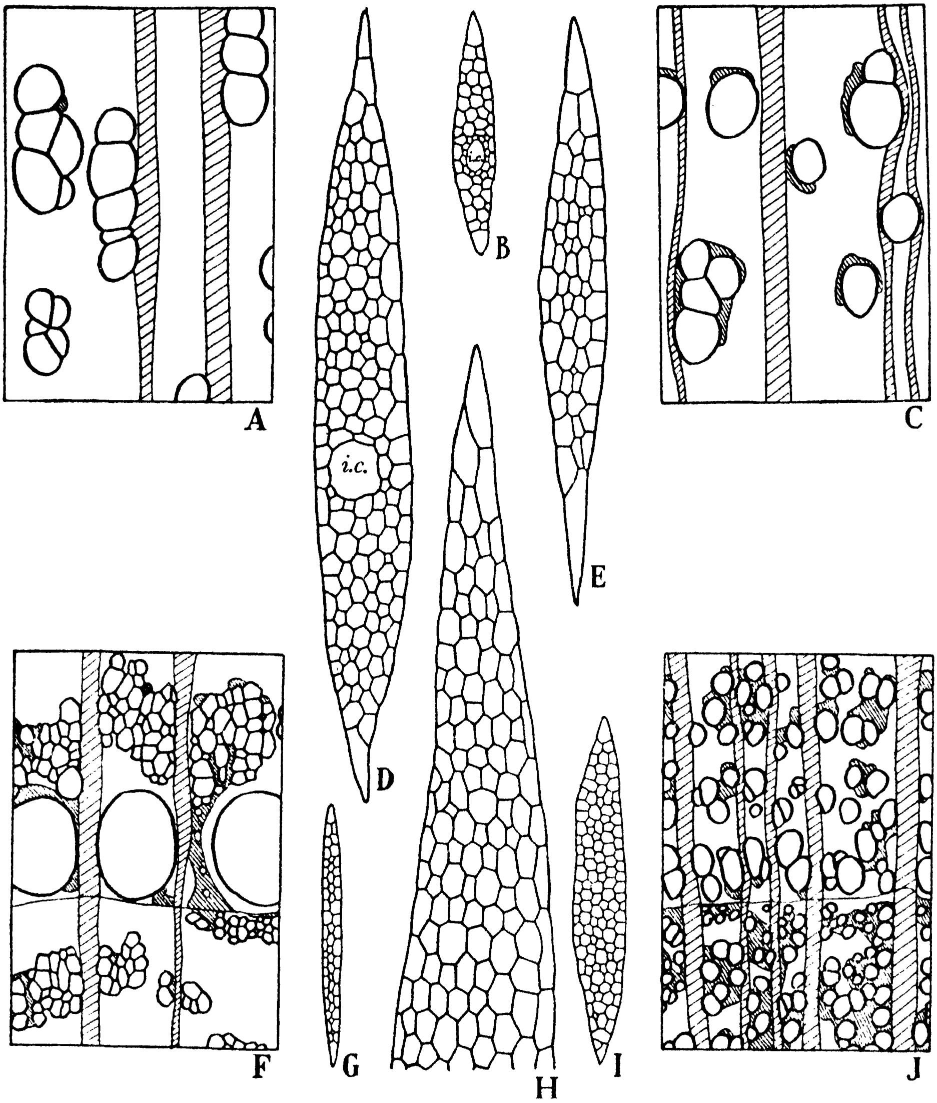


FIG. 170. *ARALIACEAE*

A, *Cussonia arborea* Hochst. B, *Acanthopanax malayanus* Hend. C, *Panax murrayi* F. v. M. D, *Cussonia arborea* Hochst. E, *Polyscias kikuyuensis* Summerhayes. F, *Kalopanax pictus* Nakai. G, *Acanthopanax sciadophylloides* Franch. et Sav. H, *Aralidium pinnatifidum* Miq. I, *Hedera helix* Linn. J, *Hedera helix* Linn.

i.c. Intercellular canal.

some species of *Agalma*, *Aralia*, *Aralidium*, and *Brassaiopsis*; usually less than 1 mm. high, occasionally more than 2 mm. high, e.g. in *Aralidium*, *Boerlagiodendron*, and *Macropanax*; uniseriates typically very few and often only a few cells high, composed entirely of square to upright cells, or with some procumbent cells, occasionally composed of procumbent cells only, e.g. in *Hedera helix* L.; 1–8, mostly 3–5, rays per mm.; heterogeneous (Kribs's Type IIA and B), commonly with only a single marginal row of square to upright cells and sometimes almost homogeneous, e.g. in species of *Dendropanax* and *Didymopanax*; homogeneous (Kribs's Type I) in *Hedera* (Fig. 170 I) and *Textoria*; more markedly heterogeneous and commonly with 2–3 marginal rows in *Aralidium*, *Arthrophyllum*, *Heteropanax*, *Meryta*, *Pseudopanax*, *Reynoldsia*, and *Trevesia*; composed almost entirely of square to upright cells in *Harmsiopanax*; the procumbent cells varying in size from small, e.g. in *Acanthopanax* (Fig. 170 G), *Aralia*, *Gamblea*, *Hedera*, and *Textoria*, to coarse, e.g. in *Aralidium* (Fig. 170 H), *Macropanax*, *Reynoldsia*, and *Trevesia*. Sheath cells often present and sometimes very pronounced, e.g. in *Agalma*, *Aralia*, *Heteropanax*, *Meryta*, *Pseudopanax*, *Tetrapanax*, and *Trevesia*. **Fibres** with small simple pits, mostly on the radial walls and often rather few even there. Commonly septate, particularly round the vessels; septate fibres observed or reported in species of *Agalma*, *Aralia*, *Aralidium*, *Arthrophyllum*, *Boerlagiodendron*, *Brassaia*, *Brassaiopsis*, *Cussonia*, *Dendropanax* (1154), *Didymopanax*, *Dizygotheca* (376), *Gamblea*, *Gilibertia*, *Harmsiopanax*, *Hedera*, *Heptapleurum* (1154, 1206), *Heteropanax*, *Horsfieldia* (1154), *Kalopanax*, *Macropanax*, *Meryta*, *Oreopanax* (1206), *Osmoxylon* (1206), *Panax*, *Pentapanax*, *Polyscias*, *Pterotropia* (376), *Schoepfera*, *Sciadodendron* (376), *Tieghemopanax* (376), and *Trevesia*. Walls thin to moderately thick. Mean length usually 0·7–1·6 mm. but F. B. H. Brown gives 0·2 mm. for *Panax gaudichaudii* DC.; such figures as are available appear to show that the fibres are on the average seldom more than half as long again as the vessel members. **Intercellular canals,** small to large, present in the rays of some species of *Acanthopanax* (Fig. 170 B), *Arthrophyllum*, *Brassaia*, *Cheirodendron*, *Cussonia* (Fig. 170 D), *Dendropanax* (1886), *Didymopanax*, *Dizygotheca*, *Gilibertia*, *Heptapleurum* (1154), *Heteropanax*, *Myodocarpus* (1851), *Nothopanax* (1851), *Oreopanax*, *Panax* (282), *Schefflera* (1851), *Sciadodendron* (376), *Textoria*, and *Tieghemopanax* (525). Record and Hess (1886) note that these canals are not always consistently present in a species.

ROOT

Secretory canals in the young root are situated opposite the strands of primary phloem and primary xylem and thus displace the lateral branches. (Arrangement similar in the Umbelliferae.)

Secretory canals in the root of *Aralia nudicaulis* Linn. and *Aralia quinquefolia* Decne. et Planch. recorded by Holm (1071). Tuberous root of *A. quinquefolia* including a pith.

TAXONOMIC NOTES

The genera in this family are not very clearly defined, and certain species have been transferred from one genus to another by different authors. Kano (1217), who made a special study of 11 species of *Acanthopanax* and related genera, placed them all in *Acanthopanax* and *Kalopanax* which he claims can be distinguished from each other by the anatomical characters of their vegetative organs. At the same time he united *Eleutheropanax* and *Evodiopanax* with *Acanthopanax*. According to Kano, *Acanthopanax* can be distinguished by the following characters. The cortical parenchyma divided into 3 distinct zones; the sinuous pericycle consisting of fibres and parenchyma or exclusively of parenchyma; the large or medium-sized epidermal cells and the precocious development of the cork; the absence of fibres from the petiolules and veins; the cluster crystals confined to the mesophyll. *Kalopanax*, on the other hand, can be distinguished from *Acanthopanax* by the homogeneous cortical parenchyma; the circular pericycle containing fibres with narrow lumina; the small epidermal cells of the axis and the late development of cork; the presence of pericyclic fibres in the petiolules and principal veins; the clustered and solitary crystals confined to the region of the veins. Kano also divided *Acanthopanax* and *Kalopanax* into groups of species on the basis of anatomical structure, and found it possible to identify species by the size of the epidermal cells of the lamina, the shape of the petiole in transverse sections and the arrangement of the petiolar vascular bundles. To the present writer it seems probable that difficulties would arise in using Kano's methods of identification except in studies confined to the species which he examined.

Viguier (2335) has pointed out that the anatomical structure of *Dizygotheca*, and especially the structure of the pith, differs somewhat from the other genera of Araliaceae which he examined.

Guillaumin (841) has demonstrated that the anatomical characters of *Fatshedera lizei* Guill. are intermediate between those of the species of *Fatsia* and *Hedera* which are generally accepted as the parents of this intergeneric hybrid.

Hoar (980), who made a comparative study of the stem structure of the Umbelliflorae, concluded that the Cornaceae should not be placed in the same cohort as the Araliaceae and Umbelliferae.

In spite of their different habits, the Araliaceae and Umbelliferae possess many important anatomical features in common. In the wood anatomy the resemblance is marked, including such features as paratracheal parenchyma, wide rays, intercellular canals in the rays, and vessel characters; both families possess a more highly specialized ray type than might be expected from the degree of specialization of the vessel and both are unusual for the scarcity of uniseriate rays in woods with heterogeneous multiseriate rays. The chief difference is the absence of septate fibres from the Umbelliferae.

Economic Uses

Rice paper is prepared in Formosa from the pith of *Tetrapanax papyrifer* (Hook.) K. Koch (*Fatsia papyrifer* Benth. et Hook.). Virginian Sarsaparilla, derived from *Aralia nudicaulis* Linn., has been used in medicine, but its value is not well established. Ginseng, a variety of *Aralia quinquefolia* Decne. et Planch., native of north China, has also been used in medicine. Anatomical details concerning these last 2 species have been published by Diepenbrock (587) and Holm (1071). The presence of secretory canals at once serves to distinguish this material from true Sarsaparilla (*Smilax* spp., Family Liliaceae).

The woods of this family are typically light coloured and soft, and though used locally for packing-cases, matches, and general carpentry, are not of any great importance.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Acanthopanax,* Anomopanax, Apiopetalum, Aralia,* Arthrophyllum, Astrotricha, Boerlagiodendron, Bonnierella, Brassaia, Brassaiopsis, Cephalaralia, Cheirodendron, Cuphocarpus, Cussonia, Delarbrea, Dendropanax, Didymopanax, Dizygotheca,* Echinopanax, Eremopanax, Fatshedera,* Fatsia,* Gamblea, Gastonia, Hedera,* Heteropanax, Horsfieldia, Kalopanax, Kissodendron, Mackinlaya, Macropanax, Meryta, Motherwellia, Myodocarpus, Nothopanax,* Oreopanax, Panax, Pentapanax, Plerandra, Polyscias,* Porospermum, Pseudopanax, Pseudosciadium, Pterotropia, Reynoldsia, Schefflera, Sciadopanax, Sciadophyllum, Stilbocarpa, Strobilopanax, Tetrapanax, Tetraplasandra, Tieghemopanax, Trevesia, Tupidanthus.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Acanthopanax, Agalma, Aralia, Aralidium, Arthrophyllum, Boerlagiodendron, Brassaia, Brassaiopsis, (Cheirodendron), Cussonia, Dendropanax, Didymopanax, (Dipanax), Dizygotheca, Fatsia, Gamblea, Harmsiopanax, Hedera, Heptapleurum, Heteropanax, Kalopanax, Macropanax, Meryta, (Oreopanax), Panax, (Pentapanax), Polyscias, Pseudopanax, (Pterotropia), Reynoldsia, Schefflera, (Sciadodendron), (Tetraplasandra), Textoria, (Tieghemopanax), Trevesia.

LITERATURE

(i) *On General Anatomy*

Bowman **250**, Davies **550**, Diepenbrock **587**, Guillaumin **841**, Haar **856**, Hoar **980**, Holm **1071**, Joshi **1195**, Kano **1217**, Smith **2135**, Viguier **2334**, **2335**.

(ii) *On Wood Structure*

Bailey **78**, de Bastos **147**, Benoist **170**, den Berger **182**, British Honduras Forestry Department **274**, Brown, F. B. H. **282**, Burgerstein **310**, **312**, Chalk and Chattaway **358**, Chattaway **376**, Cozzo **494**, Dadswell **525**, Dadswell and Record **533**, Desch **574**, Fujioka **732**, Giordano **786**, Greguss **2522**, Hoar **980**, Howard **1088**, Janssonius **1154**, Jolly **1188**, Kanehira **1206**, **1209**, Lecomte **1334**, Record **1783**, **1801**, **1814**, **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**, Tang **2230**, **2231**, Tupper **2295**, Viguier **2334**, **2335**, Webber **2377**, Williams **2430**, Yamabayashi **2478**.

158. CORNACEAE

(FIG. 171 on p. 738; FIG. 172 on p. 742; FIG. 174 on p. 750)

SUMMARY

(i) GENERAL

A widely distributed but mainly temperate family, consisting chiefly of trees and shrubs, but including a few herbs. The **leaf** is always dorsiventral. Simple, unicellular **hairs** occur generally, but 2-armed and glandular types are also present in certain species. The non-glandular hairs are sometimes sufficiently numerous to form a dense tomentum on the lower surface of the leaf. The ranunculaceous **stomata** are confined to the lower side of the leaf. In the young **stem** the thin-walled **cork** arises superficially; the primary **cortex** tends to be collenchymatous; the **pericycle** usually contains isolated strands of fibres or exhibits transitional stages between this and a composite, continuous ring of sclerenchyma. In the **xylem** the predominantly solitary vessels are often angular in transverse section and the perforation plates nearly always scalariform with many bars. **Secretory canals** occur in the larger veins of the leaf and in the pith of the stem in *Mastixia.* **Crystals** of calcium oxalate may be solitary, clustered, or in the form of crystal-sand.

(ii) WOOD

Vessels small, exclusively solitary, numerous, sometimes with spiral thickening, perforation plates typically scalariform with many bars, but occasionally simple, intervascular pitting rare, opposite to scalariform, pits to parenchyma usually round, members moderately to very long. **Parenchyma** sparse, typically diffuse, rarely scanty paratracheal. **Rays** up to 8 cells wide, markedly heterogeneous, more than 1 mm. high. **Fibres** with large bordered pits, sometimes with fine spiral thickening, medium-sized to moderately long. Vertical **intercellular canals** sometimes present in *Mastixia.*

LEAF

Always dorsiventral. **Hairs,** sometimes sufficiently numerous to form a tomentum on the lower surface, e.g. in *Corokia*, *Curtisia*, and *Melanophylla*; including the following kinds. (i) Simple unicellular types, generally distributed. The hairs in this category are provided with granular, nodular, or verrucose prominences in *Griselinia.* (ii) Unicellular, 2-armed, sometimes encrusted with calcium carbonate in *Cynoxylon* (*Cornus*) (Fig. 174 B–C); similar but 2-celled hairs also occur, e.g. in *Corokia* (Fig. 174 D–F). (iii) Glandular hairs consisting of 3 or 4 cells recorded in *Toricellia*, and shortly stalked ones with spherical heads in *Melanophylla.* Margin of the lamina and wings of the petiole in *Cynoxylon floridum* (Linn.) Raf. Alsog. (syn. *Cornus florida* Linn.) and *Dendrobenthamia japonica* Sieb. et Zucc. (syn. *Cornus kousa* Buerger) said by Kano (1218) to contain mechanical tissue ('Helicenchym') consisting of prosenchymatous elements with unlignified spiral thickenings. A similar structure was previously described by Holm (1040) in leaves from the seedling, but not from the mature plant, in *Cynoxylon floridum.* Upper **epidermis** papillose in *Chamaepericlymenum canadense* (Linn.) Aschers et Graebn. (syn. *Cornus canadensis* Linn.); lower epidermis papillose in species of *Aucuba*, *Cornus* (papillae sometimes coronulate and interconnected by a reticulum of cuticular ridges), *Toricellia.* Outer walls of the epidermal cells thickened in species of *Corokia*, *Curtisia*, and *Griselinia.* Epidermis mucilaginous in some species of *Cornus.* **Hypoderm** present on the upper side in *Griselinia*; the component cells sometimes larger than those of the epidermis, and provided with thickened, pitted cells. **Stomata** ranunculaceous; confined to the lower surface. **Mesophyll,** according to Faure (673), including a single layer of palisade in *Cornus* and *Curtisia*; 1 or 2 layers in *Mastixia*; 2 layers in *Cornus* and *Griselinia*; 1–3 layers in *Aucuba*; 2 or 3 layers in *Corokia*; 1–4 layers poorly developed in *Melanophylla*; palisade scarcely differentiated in *Helwingia*, *Kaliphora*, and *Toricellia.* Mesophyll containing sclerenchymatous idioblasts in certain species of *Griselinia* and *Mastixia.* **Midrib,** according to Faure, usually provided with a single vascular strand, e.g. in *Aucuba*, *Corokia*, *Curtisia*, *Griselinia*, *Kaliphora*, and *Macrocarpium* *mas* (Linn.) Nakai (syn. *Cornus mas* Linn.); including more than 1 vascular strand in *Griselinia* (a few species), *Mastixia*, *Melanophylla*, *Toricellia*. Sclerenchyma absent from around the vascular bundles of the veins in species of *Aucuba*, *Cornus* (pro parte), *Corokia*, *Griselinia*, *Helwingia*, *Kaliphora*, but present above and below the bundles in the remaining genera, and wholly surrounding the vascular strands in *Mastixia*. **Petiole** (Fig. 172 B and F–H) exhibiting a diversity of structure in transverse sections through the distal end. Described by Faure (673) as including a single vascular strand in a few species of *Griselinia* and in *Macrocarpium mas* as well as *Corokia* and *Kaliphora*; several distinct strands in *Aucuba*, *Cornus* (most species), and certain species of *Griselinia* and *Melanophylla*; with an inconstant number of irregularly distributed bundles in *Curtisia*, *Mastixia*, *Toricellia*. The following petiolar structure seen in material examined at Kew. (i) An arc consisting of a few separate strands in *Aucuba japonica* Thunb. (Fig. 172 G). (ii) A solitary, shallow, crescentic bundle in *Davidia involucrata* Baill. var. *vilmoriniana* Wang. (Fig. 172 F), *Griselinia littoralis* Raoul, and *Macrocarpium mas*. (iii) A solitary crescentic strand with a flat adaxial bundle between the ends of the crescent in *Cornus macrophylla* Wall., *Cynoxylon nuttallii* (Audub.) Shafer (syn. *Cornus nuttallii* Audub.) (Fig. 172 H), *Helwingia japonica* (Thunb.) Dietr. (Fig. 172 B). (iv) As (iii) but with the adaxial strand separated into 2 parts in *Cornus sanguinea* Linn. Additional subsidiary strands noted in the wings of *Cynoxylon nuttallii* and *Griselinia littoralis*. **Secretory canals** recorded in the medullary portion of the larger veins in *Mastixia*. Clustered **crystals** frequent beneath the palisade tissue and beside the vascular bundles in species of *Cornus*, and observed in the cortical region of the petiole in *Griselinia littoralis*. Large solitary crystals also said to occur in the mesophyll of *Curtisia*. Crystal-sand recorded in *Aucuba*, *Cornus*, *Kaliphora*, *Melanophylla*, *Toricellia*. Crystals absent from the mesophyll in species of *Corokia*, *Helwingia*, *Toricellia*. Deposits of calcium carbonate recorded by Pfeiffer (1707) in *Cornus sanguinea*, and **fat bodies** by Solereder in the dried leaf of species of *Cornus* and *Corokia*.

AXIS

YOUNG STEM (Fig. 172 I)

Epidermis long persistent; the outer walls much thickened and/or cuticularized in species of *Aucuba*, *Cornus*, *Griselinia*, and *Helwingia* examined at Kew. Strongly cuticularized epidermis also recorded in *Mastixia*. **Cork** arising superficially in species of *Cornus*, *Corokia*, *Griselinia* and probably in other genera as well; usually composed of cells with thin walls and wide lumina, e.g. in *Cornus* and *Melanophylla*; especially well developed according to Faure (673) in *Corokia*, *Kaliphora*, *Toricellia*. Primary **cortex** generally tending to be collenchymatous, either wholly or at the periphery, except in *Mastixia*; including stone cells in species of *Cornus* (rare), *Mastixia*, and *Melanophylla*, and **cortical bundles** (leaf traces) in *Mastixia*. **Pericycle** usually containing large or small, isolated strands of fibres, e.g. in *Cornus*, *Griselinia*, *Toricellia*; with fibre strands and stone cells in species of *Cornus*, *Helwingia*, and *Mastixia*; a composite, continuous ring of sclerenchyma sometimes present in *Curtisia*, *Griselinia*, *Melanophylla*. Pericyclic sclerenchyma frequently absent from *Aucuba*, *Helwingia*, and *Kaliphora* (rare fibres recorded

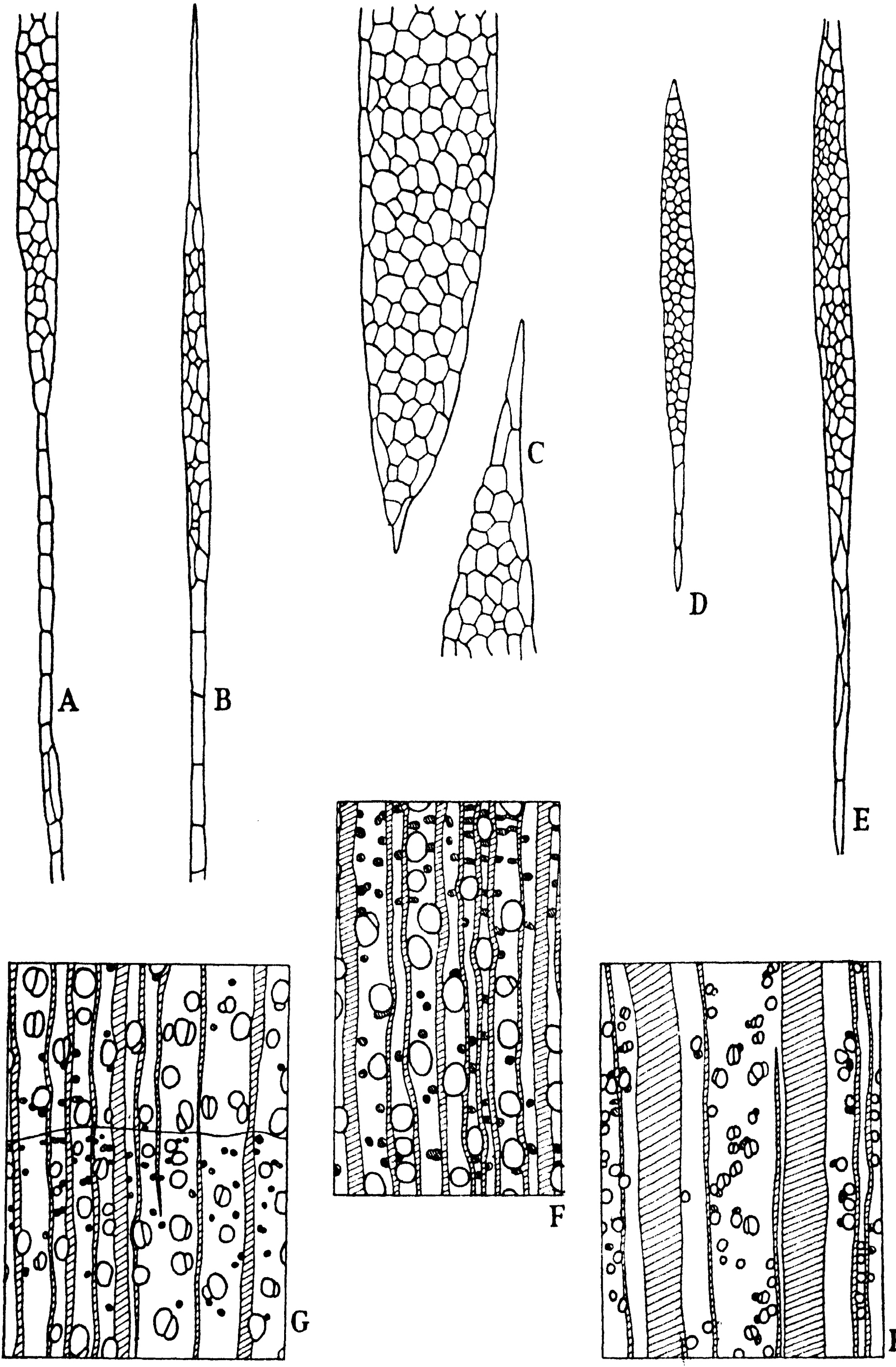


Fig. 171. *CORNACEAE*

A, *Curtisia faginea* Ait. B, *Mastixia tetrandra* C. B. Clarke. C, *Aucuba japonica* Thunb. D, *Cornus macrophylla* Wall. E, *C. peruviana* Macbr. F, *Curtisia faginea* Ait. G, *Cornus sanguinea* Linn. H, *Aucuba japonica* Thunb.

in this genus). Walls of the pericyclic fibres yellow in *Corokia*, *Griselinia*, *Mastixia*, *Toricellia*, but white in *Aucuba*, *Cornus*, *Curtisia*. Secondary **phloem** known to include fibres only in *Mastixia*, but sclerosed parenchymatous elements recorded in *Corokia* and *Cornus*. **Xylem** forming a continuous cylinder traversed by narrow rays in the species of *Aucuba*, *Cornus*, *Corokia*, *Griselinia*, and *Helwingia* examined at Kew, and probably similar in other genera as well; relatively wide primary rays noted in *Griselinia* (Fig. 172 I). Scalariform perforation plates in the vessels also observed in the genera just mentioned; simple perforations less frequent. **Pith** composed of thin-walled cells in species of *Aucuba*, *Kaliphora*, *Mastixia*, *Melanophylla*, *Toricellia*, of thickened or sclerosed cells in species of *Corokia*, *Curtisia*, *Griselinia*, *Helwingia*, including groups of sclerosed cells in species of *Cornus*, *Mastixia*, *Melanophylla*. **Secretory elements.** Canals occur in the pith and, according to Hoar (980), the cortex of *Mastixia*. Secretory cells, with unidentified contents, noted in the parenchymatous tissues in *Cornus*, *Corokia*, *Griselinia*, their number and exact distribution varying in different species. Similar cells also reported by Faure (673) to occur in the fruits of *Macrocarpium mas*. **Crystals** of the same kinds as those described under 'Leaf'; clusters observed in species of *Cornus*, *Griselinia*, and *Helwingia*, but not in *Corokia cotoneaster* Raoul. Deposits of calcium carbonate recorded by Pfeiffer (1707) in *Cornus sanguinea* Linn.

WOOD (Fig. 171)

Vessels moderately to very small (25–100 μ mean tangential diameter); usually exclusively solitary (apart from tangential pairs due to overlapping ends) but with some radial pairs in a few species of *Cornus*, e.g. *C. macrophylla* Wall., and *Lautea*; 30–90 per sq. mm., least numerous in some species of *Cornus* and in *Mastixia*; sometimes with a slight tendency to ring porousness in *Aucuba* and *Cornus*; spiral thickening observed in *Aucuba* and reported (2158) in *Cornus oblonga* Wall. and *Toricellia*. Perforation plates scalariform, except in *Kaliphora* and *Toricellia* (2158), oblique and with many fine bars. Intervascular pitting very difficult to find owing to the absence of true pairs, typically opposite but scalariform in *Mastixia*; pits to ray and wood parenchyma typically small and round, but scalariform in *Mastixia*; the sieve-like structures reported by Janssonius (1154) for *Mastixia*, according to Bailey (78) are probably artefacts and not vestured pits. Mean member length 0·7–1·9 mm. **Parenchyma** typically apotracheal, scattered among the fibres (Fig. 171 G and F), but paratracheal, as occasional cells touching the vessels in *Aucuba* (Fig. 171 H); sometimes extremely sparse, e.g. in *Lautea*. Strands commonly of 8 or 16 cells. **Rays** of 2 sizes, up to 3–8 cells wide; multiseriate rays more than 1 mm. high, except in *Lautea*, and commonly more than 2 mm. in *Aucuba*, *Curtisia*, and *Mastixia*; uniseriates numerous, composed entirely of upright cells (except in *Cornus macrophylla* Wall.) and moderately low, but more than 1 mm. high in *Curtisia* and *Mastixia*; 8–17 rays per mm.; markedly heterogeneous (Kribs's Type I), commonly with 5–10 marginal rows of square or upright cells and sometimes with more, e.g. in *Curtisia* and *Mastixia*; irregular sheath cells often present, but lacking from some species of *Cornus*, *Cynoxylon*, and *Lautea*. **Fibres** typically with large, often conspicuous bordered pits that are equally numerous on both radial and tangential walls, but, according to Solereder, with simple pits and occasionally septate in *Helwingia* and *Toricellia*, and with both simple and bordered pits in *Aucuba* and *Corokia*. Solereder also notes delicate spiral thickening in *Aucuba* and *Cornus oblonga*. Walls moderately to very thick. Mean length 0·8–2·2 mm. Vertical **intercellular canals** occur in tangential rows in *Mastixia rostrata* Bl. and *M. trichotoma* Bl. (1154).

ROOT

The following information has been recorded by Faure (673). **Cork** consisting of 2–5 layers of thin-walled cells in species of *Aucuba*, *Griselinia*, *Helwingia*, and of very thick-walled cells in *Cornus*. **Pericycle** including a composite ring of sclerenchyma in *Aucuba* and *Helwingia*. **Phloem** generally well developed. **Xylem** traversed by rays 1–2 cells wide in *Aucuba* and *Helwingia* or sometimes by rays 5 cells wide in *Griselinia*; composed of fibres with bordered pits in *Griselinia*; including infrequent vessels in *Helwingia*; vessels with bordered pits or scalariform pitting more numerous and embedded in a ground tissue composed of prosenchymatous elements with bordered pits in *Aucuba* and *Cornus*.

TAXONOMIC NOTES

Solereder and Wangerin (2358) in their respective works have published a key, originally devised by Sertorius, to the genera of Cornaceae based on anatomical characters. *Mastixia* is distinguished from the remainder of the family by the occurrence of secretory canals in the pith and possibly the cortex. It is interesting to note that the anatomy of the Cornaceae differs in many respects from that of the Araliaceae and Umbelliferae, whilst the last 2 families have points in common. This observation, made at Kew, fully confirms the opinion previously expressed by Hoar (980) that the Cornaceae should not be included in the same cohort as the Araliaceae and Umbelliferae. Hoar also concluded that the Nyssaceae and Davidioideae should be separated from the Cornaceae, and expressed the view that the presence of secretory canals is not necessarily of importance in determining the relationship of the genus.

The wood anatomy is in many respects similar to that of the Hydrangeaceae, e.g. *Philadelphus*. The chief difference lies in the parenchyma; in both families this is often very sparse or absent, but where it is more abundant it tends to be paratracheal in the Hydrangeaceae, e.g. in *Philadelphus incanus* Koehne, whereas in the Cornaceae it is apotracheal and only associated with the vessels in *Aucuba*.

In the present book the new names proposed by Hutchinson (1113) for species previously included in *Cornus* have been used as far as possible, but the name *Cornus* has also been used in a wide sense when citing information recorded in the literature.

ECONOMIC USES

The bark of *Cynoxylon floridum* (Linn.) Raf. Alsog. (syn. *Cornus florida* Linn.) and closely related species has been employed in medicine as a substitute for that of *Cinchona*, but its use for this or for other medicinal purposes is now insignificant. Faure (673) has described the anatomical structure of these barks. The microscopical characters of the bark of *Cynoxylon floridum*, according to Faure, include the following: 5 or 6 layers of cork cells with thickened walls; poorly developed phelloderm; cortical parenchyma consisting of roundish cells; phloem containing irregularly distributed groups of pitted, sclerosed cells with narrow lumina; cluster crystals of calcium oxalate in the cortical and pericyclic regions; absence of starch; a small amount of tannin in the region of the cork.

The wood of *Cynoxylon* (*Cornus* p.p.), e.g. the Dogwood or Cornel, *Cynoxylon floridum* (Linn.) Raf. Alsog. (syn. *Cornus florida* L.), and *Cynoxylon nuttallii* (Audub.) Shafer (syn. *Cornus nuttallii* Audub.), is used for a variety of purposes requiring a smooth, hard, and fine-textured wood, e.g. as shuttles for textile weaving, small pulleys, and jewellers' blocks.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Aucuba,* Chamaepericlymenum, Cornus,* Corokia,* Curtisia, Cynoxylon,* Dendrobenthamia, Griselinia,* Helwingia,* Kaliphora, Macrocarpium,* Mastixia, Melanophylla, Toricellia.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Aucuba, Cornus, (Corokia), Curtisia, Cynoxylon, (Helwingia), (Kaliphora), Lautea, Macrocarpium, Mastixia, (Toricellia).

LITERATURE

(i) *On General Anatomy*

Faure **673**, Hoar **980**, Holm **1040**, Hutchinson **1113**, Kano **1218**, Olsen **1638**, Pfeiffer, H. **1707**, Starr **2188**, Wangerin **2358**.

(ii) *On Wood Structure*

Bailey **78**, Beekman **167**, den Berger **179**, **182**, Brown **283**, Brown, H. P. and Panshin **288**, Chalk *et al.* **360**, Dadswell and Record **533**, Greguss **2522**, Hoar **980**, Howard **1088**, Janssonius **1154**, Kanehira **1206**, **1209**, Lecomte **1334**, Record **1783**, **1787**, **1800**, **1801**, **1818**, **1843**, **1851**, **1884**, Record and Hess **1886**, Scott **2075**, Sudworth and Mell **2217**, Tang **2231**, Thompson **2254**, Yamabayashi **2478**.

159. ALANGIACEAE

(FIG. 172 on p. 742; FIG. 173 on p. 746; FIG. 174 on p. 750)

SUMMARY

(i) GENERAL

The small trees and shrubs belonging to this old world tropical family exhibit features in common with the Cornaceae. The following brief description is based mainly on that of Wangerin (2357). Further particulars are to be found in Faure's (673) very detailed anatomical description of the family.

(ii) WOOD

GROUP A. *Javanicum* type

Vessels medium-sized, perforation plates scalariform, intervascular pitting alternate and rather small, pits to parenchyma often simple and elongated, members very long. **Parenchyma** apotracheal, diffuse, tending to be in short uniseriate lines, strands of 8–16 cells. **Rays** 3–5 cells wide, commonly

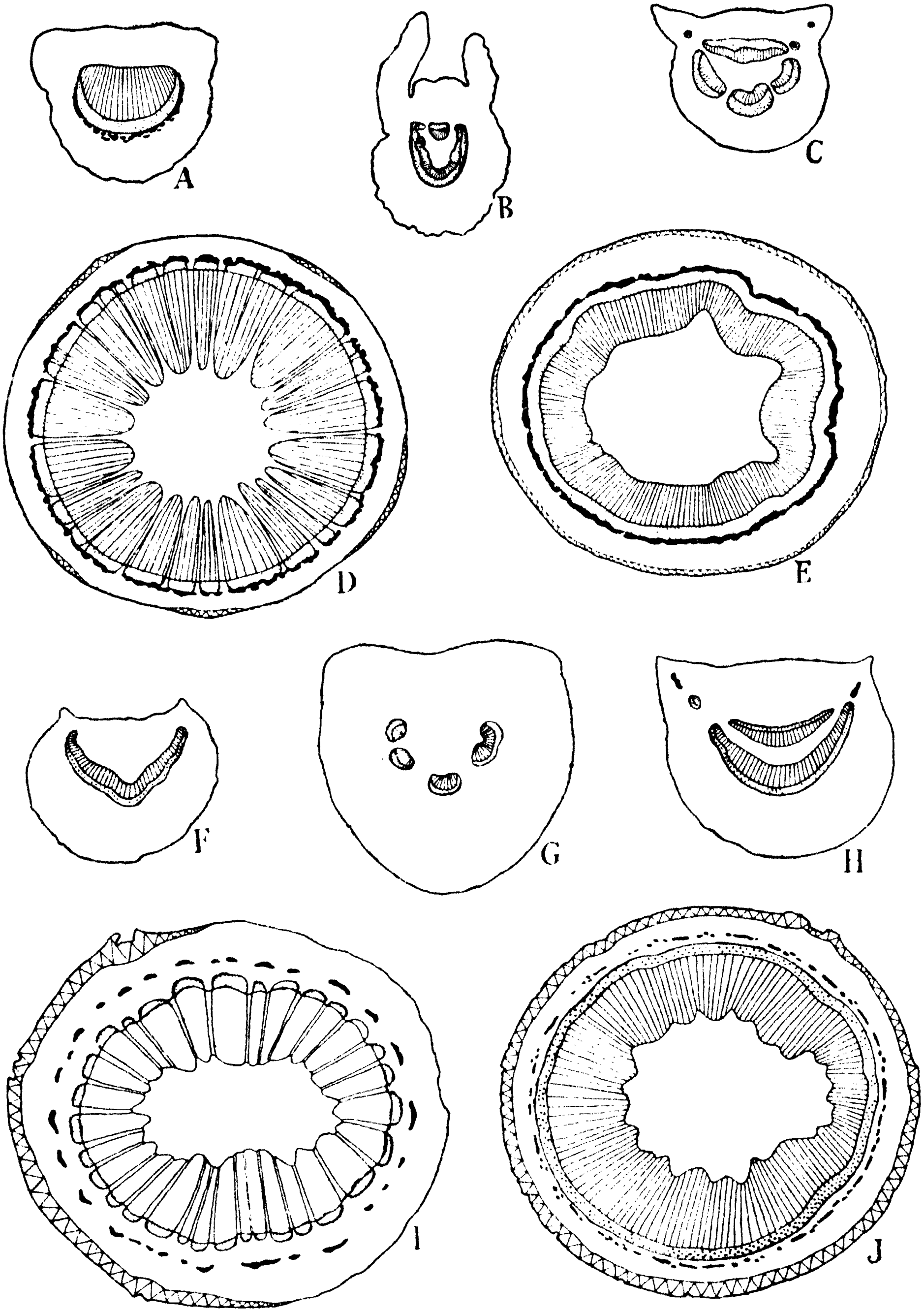


FIG. 172. *GARRYACEAE*, A and D; *CORNACEAE*, B and F–I; *NYSSACEAE*, C and E; *ALANGIACEAE*, J

A, *Garrya elliptica* Dougl. Petiole × 13. B, *Helwingia japonica* F. G. Dietr. Petiole × 28. C, *Nyssa sylvatica* Marsh. Petiole × 13. D, *Garrya elliptica* Dougl. Stem × 13. E, *Nyssa sylvatica* Marsh. Stem × 13. F, *Davidia involucrata* Baill. var. *vilmoriniana* Wang. Petiole × 8. G, *Aucuba japonica* Thunb. Petiole × 13. H, *Cynoxylon nuttallii* (Audub.) Shafer (syn. *Cornus nuttallii* Audub.). Petiole × 20. I, *Griselinia littoralis* Raoul. Stem × 13. J. *Alangium platanifolium* (Sieb. et Zucc.) Harms. Stem × 13.

2–3 mm. high, heterogeneous with 10 or more marginal rows. **Fibres** with simple pits and very to extremely long.

GROUP B. *Chinense* type

Vessels moderately small to medium-sized, perforations simple, intervascular pitting alternate and large, pits to parenchyma often simple but seldom elongated, members of medium length. **Parenchyma** as in Group A, but with strands of 4–8 cells. **Rays** 3–8 cells wide, seldom more than 1 mm. high, heterogeneous with up to about 10 marginal rows, commonly containing crystals. **Fibres** with simple pits, of medium length to moderately long.

LEAF

Usually dorsiventral, but tending to be isobilateral or centric in a few species. **Hairs** somewhat diverse, but including unicellular pointed forms sometimes in pits, others with swollen bases, and a third obtuse kind with thin walls. Stellate hairs recorded in *Alangium costatum* Wang. and glandular hairs of various types in species of *Alangium*. Hooked hairs (Fig. 174 G) also occur. Upper **epidermis** stated by Faure (673) to be papillose in *Alangium chinense* (Lour.) Rehder; palisade-like but provided with transverse walls in *Alangium ebenaceum* Griff. (syn. *Marlea ebenacea* Clarke). **Stomata** generally confined to the lower surface, but a few recorded on the upper side as well in *A. chinense*; usually ranunculaceous. **Hypoderm** towards the upper surface present in *A. nobile* (C. B. Clarke) Harms. **Mesophyll** generally including a single palisade layer and a very thick region of spongy tissue. Vascular bundles of the larger **veins** accompanied by thick-walled sclerenchymatous elements with wide or narrow lumina in different species. **Petiole** of *Alangium* with 3 isolated vascular bundles at the base, but exhibiting a single arc-shaped vascular strand in transverse sections through the distal end. Petioles with an open arc of small separate strands and others with a principal strand surrounded by small multiple bundles also recorded by Faure in different species of *Alangium*. Very large cluster **crystals** occur in the mesophyll and sometimes appear as transparent dots in the leaf, e.g. in *A. chinense* and *A. ebenaceum*. Solitary crystals also recorded, especially near the vascular bundles. Crystals absent from *A. nobile*. Refractive **fat bodies** stated by Solereder to occur in the dried leaf of *Alangium*. The formation of hemispherical **intumescences,** composed of thin-walled vacuolated cells and situated below the stomata on the lower surface of the leaf of *A. chinense*, are described by Orr (1639). The intumescences arise when the atmosphere is sufficiently moist and the temperature sufficiently high.

AXIS

YOUNG STEM (Fig. 172 J)

Cork consisting of only a few layers of fairly thin-walled cells. **Cortex** narrow; partly collenchymatous. **Pericycle** containing isolated strands of yellow or white fibres. **Xylem** traversed by rays 1–2 cells wide; including vessels with simple perforations in many species of *Alangium*, but scalariform plates also occur in certain species; ground tissue consisting of thin- or thick-walled prosenchymatous elements with simple pits. **Pith** cells with thin or thick walls in different species. Rare cluster **crystals** recorded in the pericyclic region; and elongated, tanniniferous cells in the pith.

WOOD (Fig. 173 D–E and G–J)

GROUP A. Vessels with scalariform perforation plates and small intervascular pitting, vessel members and fibres very long (Fig. 173 I, J).

Alangium ebenaceum Griff., *A. javanicum* (Koord. et Val.) Wang., *A. nobile* (Clarke) Harms., *A. ridleyi* King, *A. sessiliflorum* Merr.

Vessels medium-sized (100–200 μ mean tangential diameter); multiples of 2 or 3 cells very common and with some of 4 or more cells; overlapping ends commonly giving rise to regular pairs of multiples (Fig. 173 I) and irregular clusters; 4–7 per sq. mm. Perforation plates scalariform, typically with fewer than 10 rather thick bars, but occasionally with more, moderately oblique. Intervascular pitting alternate, small; pits to ray and wood parenchyma frequently simple and elongated horizontally. Tyloses sometimes present. Mean member length 1·3–1·8 mm. **Parenchyma** moderately abundant, apotracheal, as short uniseriate lines and scattered cells; strands of 8–16 cells. **Rays** up to 3–5 cells wide; commonly 2–3 mm. high; with numerous uniseriates composed of upright cells; 11–13 rays per mm.; heterogeneous (Kribs's Type I), the multiseriate parts high and with sides tending to be parallel, with 10 or more marginal rows of square or upright cells. Crystals only rarely present, e.g. in *A. ridleyi*. **Fibres** with simple pits and very thick walls; mean length about 3 mm.

GROUP B. Vessels with simple perforations and large intervascular pitting, vessel members and fibres typically of medium length (Fig. 173 D, E, G, H).

Alangium chinense (Lour.) Rehder, *A. longiflorum* Merr., *A. lamarckii* Thw., *A. vitiense* (A. Gray) Harms.

Vessels typically moderately small (50–100 μ mean tangential diameter), but up to 150 μ in *A. chinense*; multiples of 2 or 3 cells common and with some of 4 or more cells, the latter and the pairs due to overlapping ends less common than in Group A; 5–8 per sq. mm.; semi-ring-porous in some specimens of *A. chinense* (Fig. 173 H). Perforations simple. Intervascular pitting alternate and large (only moderately large in *A. vitiense*), pits to ray and wood parenchyma often simple, but seldom elongated (elongated pits moderately common in *A. vitiense*). Tyloses often present. Mean member length 0·5–0·7 mm. **Parenchyma** similar in type to that of Group A, except that in *A. chinense* it is also in uni- to biseriate terminal bands and in narrow sheaths round the vessels (Fig. 173 H); strands of 4–8 cells. **Rays** up to 7 or 8 cells wide in *A. chinense*, not more than 3 or 4 cells wide in the other species; uniseriates moderately numerous and composed of square or upright cells; rays, other than fusions, typically less than 1 mm. high; usually 12–20 per mm., but fewer (about 7) in *A. chinense*; heterogeneous (Kribs's Type II A), commonly with 5–8 marginal rows of square or upright cells, but seldom with more than 3 or 4 rows in *A. chinense* and *A. vitiense*, the multiseriate parts relatively short. Crystals very common. **Fibres** with simple pits and moderately thick to thick walls; mean length 1·0–1·9 mm. **Growth rings.** The periodicity of cambial activity in *Alangium* in Java has been investigated by Coster (481).

Two further species, *A. kurzii* Craib and *A. unilocular*e King, should probably be included in this group, from which they differ principally in the nature of the vessel pitting, the intervascular pitting being rather small and that to parenchyma including many oblong pits, as in Group A.

ROOT

The following particulars concerning the root of *A. chinense* (Lour.) Rehder have been recorded by Faure (673).

Cork well developed, composed of cells with slightly thickened walls. Groups of large sclerosed cells present beneath the cork. **Phloem** collenchymatous, in separate strands; sometimes with invaginations extending into the xylem. **Xylem** traversed by rays 4–6 cells wide composed of pitted sclerosed cells; including circular vessels. Cluster **crystals** present in all parenchymatous tissues of the root.

TAXONOMIC NOTES

(i) GENERAL

According to Wangerin (2357) *Alangium* (including *Marlea*) is distinguished from the Cornaceae by the structure of the ovule and the mode of formation of the pollen.

(ii) FROM WOOD STRUCTURE

The woods are of 2 types, which have been described separately. Group A is quite uniform and includes *Alangium ebenaceum*, *A. javanicum*, *A. nobile*, *A. ridleyi*, and *A. sessiliflorum*. Group B, which is rather less uniform, includes *A. chinense*, *A. longiflorum*, *A. lamarckii*, and *A. vitiense*. Group A is of a much less specialized general type of structure than Group B, but has a more advanced type of intervascular pitting and of fibre than is usually associated with such long vessel members.

A. chinense differs from the other genera in Group B in some respects. *A. lamarckii*, which might be expected on taxonomic grounds to differ con-considerably from the other genera in Group B, is actually very similar to *A. vitiense* and *A. longiflorum*.

GENERA DESCRIBED

FOR GENERAL ANATOMY AND WOOD STRUCTURE

Alangium.

LITERATURE

(i) *On General Anatomy*

Faure **673**, Orr **1639**, Wangerin **2357**.

(ii) *On Wood Structure*

den Berger **182**, Coster **481**, Desch **574**, Janssonius **1154**, Kanehira **1206**, Record **1843**, **1851**.

160. GARRYACEAE

(FIG. 172 on p. 742; FIG. 173 on p. 746)

SUMMARY

(i) GENERAL

Trees and shrubs belonging to the single genus *Garrya*, which comprises some 10 species from south-western U.S.A., Mexico, Guatemala, and Jamaica. The following brief description of the general anatomy is partly original and partly based on Wangerin's (2355) account. A very detailed description of the family has also been published by Faure (673), who gives particulars of anatomical differences between the species.

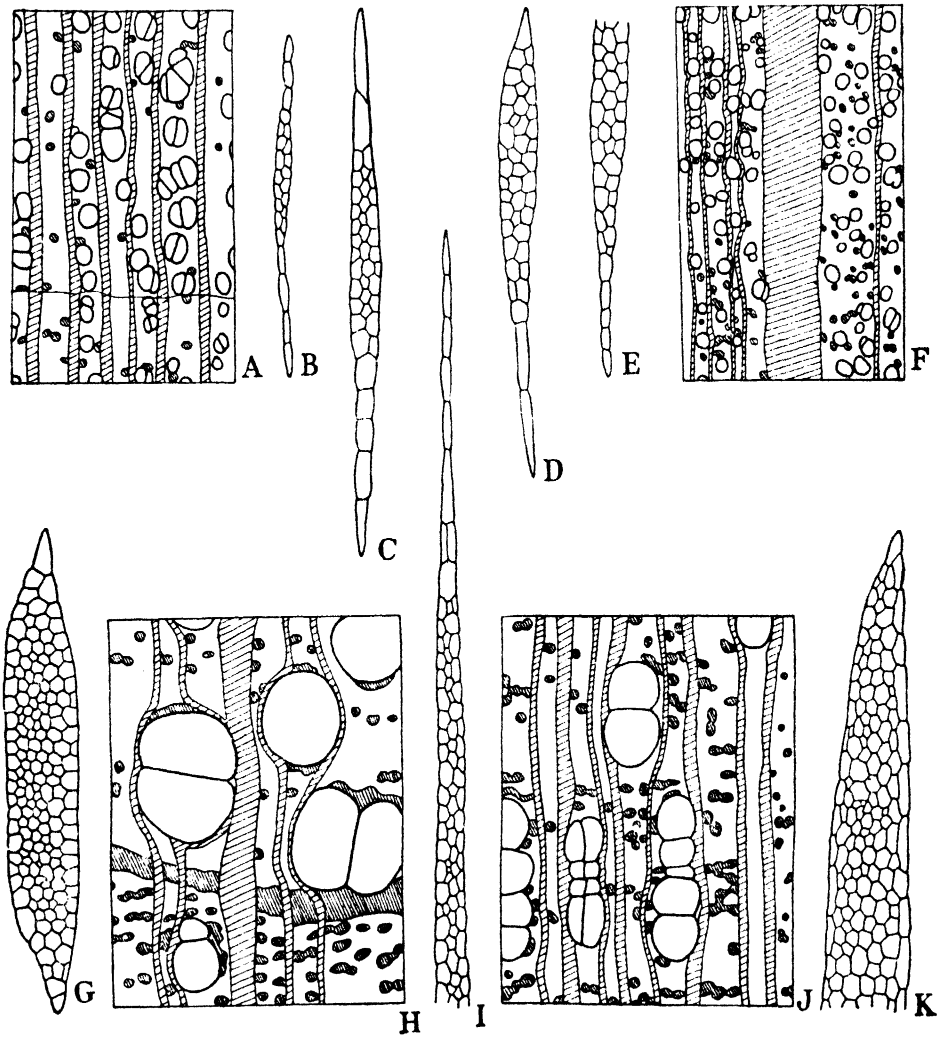


Fig. 173. *NYSSACEAE*, A–C; *ALANGIACEAE*, D–E and G–J; *GARRYACEAE*, F and K

A, *Nyssa acuminata* Small. B, *N. sylvatica* Marsh. C, *N. sessiliflora* Hook. f. D, *Alangium vitiense* (A. Gray) Harms. E, *A. lamarckii* Thw. F, *Garrya elliptica* Dougl. G, *Alangium chinense* Rehder. H, *A. chinense* Rehder. I, *A. javanicum* Wang. J, *A. javanicum* Wang. K, *Garrya elliptica* Dougl.

(ii) Wood

Vessels very small, solitary, with spiral thickening, perforation plates scalariform, pits to ray cells circular, members of medium length. **Parenchyma** diffuse. **Rays** of 2 sizes, the larger up to 8 cells wide and 2 mm. or more high, composed entirely of square or upright cells. **Fibres** with numerous bordered pits, sometimes with spiral thickening, moderately short to medium length.

LEAF

Leathery. Dorsiventral; frequently with a felt of unicellular **hairs,** especially when young. The **epidermis** is often papillose except in *G. buxifolia* Gray and *G. fadyenii* Hook. f.; papillae especially well developed in *G. wrightii* Torr. Outer walls of the epidermal cells generally strongly thickened. **Stomata** confined to the hairy lower surface; protected by beak-like extensions of the guard or subsidiary cells. A large-celled **hypoderm** present on the upper side of the leaf in several species. **Mesophyll** always including several layers of palisade cells and supported by sclerenchymatous idioblasts, the latter varying in shape and in the thickness of the walls in different species. Vascular bundles of the **midrib** and larger **veins** accompanied above and below by groups of sclerenchymatous elements. **Petiole** of *G. elliptica* Dougl. (Fig. 172 A) and *G. macrophylla* Benth. exhibiting, in transverse sections through the distal end, a solitary, slightly crescent-shaped vascular strand. **Crystal-sand** present in the mesophyll of young leaves and near the vascular bundles of the veins in older ones. Refractive **fat bodies** recorded in the mesophyll.

AXIS

YOUNG STEM (Fig. 172 D)

Cork arising in the epidermis or sub-epidermis; varying in the size of the component cells and in the thickness of the walls. Outer part of the primary **cortex** collenchymatous and the inner part lacunar in *G. elliptica* Dougl. and other species. **Pericycle** generally containing isolated strands of fibres, sometimes accompanied by stone cells, but a continuous sclerenchymatous ring present in *G. elliptica* and *G. lindheimeri* Torr. Fibres yellow in some species. **Xylem** traversed by broad primary rays, including solitary vessels with scalariform perforation plates, the latter each with a few bars; prosenchymatous elements of the ground tissue with bordered pits. Primary medullary rays fairly wide. **Pith** composed of fairly thick-walled cells, often containing **crystal-sand.** For **developmental anatomy** of the main stem as well as of the inflorescence and axillary vegetative shoots of *G. elliptica* see Reeve's (1899, 1900) articles.

WOOD (Fig. 173 F and K)

Vessels very small (25–50 μ mean tangential diameter), exclusively solitary, about 150 per sq. mm. and with spiral thickening; perforation plates scalariform, with few bars; intervascular pitting very rare, pits to ray cells typically circular and bordered; mean member length about 0·6 mm. **Parenchyma** apotracheal, scattered among the fibres and sometimes tending to form short uniseriate lines; strands usually of 4 cells. **Rays** of 2 distinct sizes, the smaller uniseriate, the larger up to 8 cells wide and up to 2 mm. or more high, but frequently dissected into smaller units; both types composed entirely of square and upright cells; about 6 rays per mm.; the larger rays usually with 1–3 marginal rows of upright cells; with sheath cells. **Fibres** with numerous distinctly bordered pits on both radial and tangential walls;

walls moderately thick to thick, and sometimes with spiral thickening (1851); about 0·9 mm. long.

ROOT

Described for *G. ovata* Benth. by Faure (673). **Cork** consisting of 4 or 5 rows of tabular cells with slightly thickened walls. **Cortex** narrow, including irregular sclerosed cells. **Pericycle** including strands of thick-walled hexagonal fibres. **Xylem** in rectangular strands, separated by rays 6 cells wide composed of sclerosed cells; including circular vessels, isolated or in pairs. **Crystal-sand** present in the vertical parenchyma and rays. **Secretory cells** with granular contents occurring in the vertical parenchyma and rays.

TAXONOMIC NOTES

Wangerin (2355) has pointed out that *Garrya* differs from the Cornaceae in having a superior ovary. He suggests that the genus may have affinities with the Amentiflorae, a view which has also been supported by Hutchinson (1113).

The wood structure is very similar to that of the Cornaceae, except for the shrubby character of the rays (composed entirely of square to upright cells). On the other hand, there does not appear to be anything in the wood anatomy that conflicts with the possibility of affinity with the Amentiflorae.

ECONOMIC USES

According to Wangerin (2355) the bark of certain species of *Garrya* contains an alkaloid and has been used as a bitter tonic.

GENUS DESCRIBED

Garrya.*

* Represented in the Kew slide collection.

LITERATURE

(i) *On General Anatomy*

Faure **673**, Hutchinson **1113**, Reeve **1899**, **1900**, Wangerin **2355**.

(ii) *On Wood Structure*

Record **1843**, **1851**, Record and Hess **1886**.

161. NYSSACEAE

(FIG. 172 on p. 742; FIG. 173 on p. 746; FIG. 174 on p. 750)

SUMMARY

(i) GENERAL

The shrubs and small trees belonging to this family, which occurs in eastern Asia and North America, exhibit many features in common with the Cornaceae. The following description of the general anatomy is partly original and partly based on Wangerin's (2356) account. Further particulars are to be found in Faure's (673) very detailed anatomical description of the family.

(ii) WOOD

Vessels small, perforation plates scalariform and usually with many fine bars, intervascular pitting opposite and pits to parenchyma similar, members very to extremely long. **Parenchyma** diffuse. **Rays** 2–4 cells wide, markedly heterogeneous. **Fibres** with bordered pits, moderately to very long.

LEAF

Dorsiventral. **Hairs** varying in length and frequency in different species; including simple, unicellular types sometimes with a granular surface, together with variously shaped unicellular glands in *Camptotheca* and *Nyssa* (Fig. 174 H–I). Most cells of the upper **epidermis** in American species of *Nyssa* and a few in those of *Camptotheca* mucilaginous; lower epidermal cells sometimes slightly papillose in *N. ogeche* Marsh. **Stomata** confined to the lower surface; tending to be rubiaceous in *Nyssa sylvatica* Marsh. **Mesophyll** including a single layer of palisade cells and slightly branched, sclerenchymatous idioblasts (Fig. 174 A) traversing the entire width of the lamina, the vascular bundles in the smaller **veins** being vertically transcurrent by thin-walled parenchyma. Sclerenchyma absent from around the vascular bundles in *Camptotheca*, *Davidia*, and *Nyssa sylvatica*, but present above and below the vascular bundles of the larger veins in other North American species of *Nyssa*, and completely surrounding the midrib in *N. javanica* (Blume) Wang. **Petiole** of *N. sylvatica* (Fig. 172 C), in transverse sections through the distal end, exhibiting an abaxial crescent of 3 separate vascular bundles with a flattened adaxial strand between the ends of the crescent; small subsidiary strands also present in the wings. Sections through the petiole of *Davidia involucrata* Baill. var. *vilmoriniana* (Dode) Wang. show a solitary, widely crescent-shaped strand with slightly incurved ends. Specially large, solitary **crystals** present in the spongy tissue of *Davidia*, and in the palisade parenchyma of *Camptotheca*; druses of various sizes also occur in the last 2 genera and in *Nyssa*. Crystals said sometimes to be absent from *N. ogeche*.

AXIS

YOUNG STEM (Fig. 172 E)

Cork arising superficially at least in *Davidia involucrata* Baill. var. *vilmoriniana* (Dode) Wang. and *Nyssa sylvatica* Marsh; composed of thick-walled cells in the last species. Primary **cortex** largely collenchymatous in *N. sylvatica*; containing stone cells in some species. **Pericycle** in *Davidia* and *Nyssa* characterized by a composite, continuous ring of sclerenchyma, and, in *Camptotheca*, by isolated strands of fibres. Pericyclic fibres yellow in *Nyssa*, but white in *Camptotheca* and *Davidia*. **Xylem** in the form of a continuous cylinder traversed by narrow rays; including vessels, with scalariform perforation plates with many bars, embedded, in *Camptotheca* and *Davidia*, in prosenchymatous ground tissue with bordered pits, and, in *Nyssa*, in similar elements with mixed simple and bordered pits. **Pith** composed of cells with numerous pits in the vertical walls. Solitary and clustered **crystals** present in the cortex and phloem of *Nyssa sylvatica*, and small solitary and clustered ones noted in *Davidia involucrata* var. *vilmoriniana*.

WOOD (Fig. 173 A–C)

Vessels small (less than 100 μ mean tangential diameter); solitary and in short multiples, and often appearing as tangential pairs owing to overlapping members; 15–80 per sq. mm.; sometimes with spiral thickening in *Nyssa* (1851, 1867, 1868). Perforation plates scalariform, the bars more than 20, except in *Camptotheca*, and sometimes, e.g. in *Davidia*, very numerous; intervascular pitting typically opposite, but sometimes scalariform locally, particularly in *Davidia*; pits to ray and wood parenchyma similar. Mean member length 1·0–2·0 mm. **Parenchyma** apotracheal, scattered among the

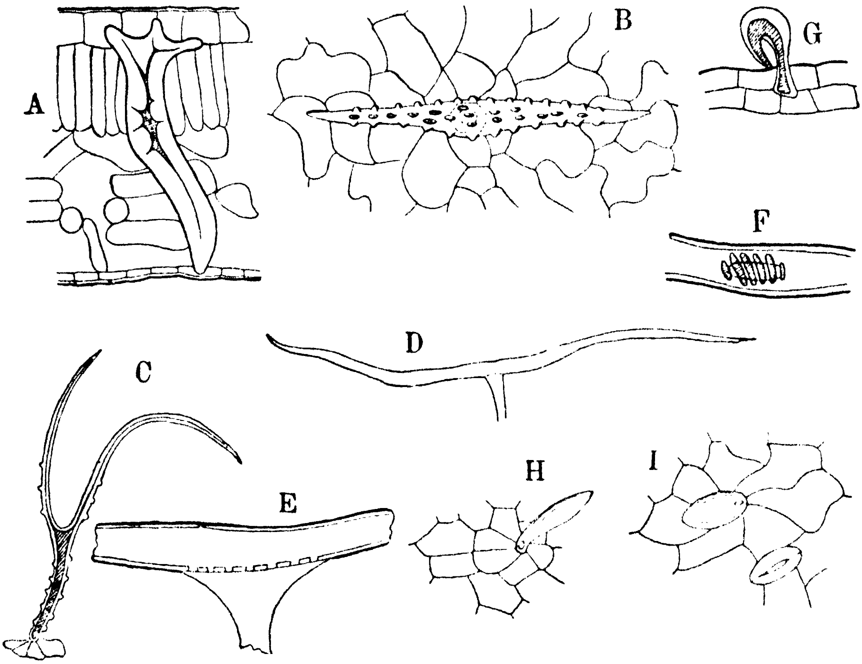


FIG. 174. *NYSSACEAE*, A, H, I; *CORNACEAE*, B–F; *ALANGIACEAE*, G

A, Portion of a transverse section of the leaf of *Nyssa caroliniana* Poir. B, C, 2-armed trichomes of *Cynoxylon nuttallii* (Audub.) Shafer (syn. *Cornus nuttallii* Audub.). B, trichome with equal arms from the upper side of the leaf. C, a similar hair but Y-shaped from the lower side of the leaf. D–F, 2-celled, 2-armed trichomes of *Corokia*. D, *Corokia cotoneaster* Raoul. E, F, *C. buddleioides* A. Cunn. E, central portion of the trichome. F, wall between the stalk and the 2-armed terminal cell, in surface-view. G, Hook-shaped hairs of *Marlea nobilis* Clarke. H, I, External glands. H, *Nyssa caroliniana* Poir. I, *Camptotheca acuminata* Decne.—By Solereder.

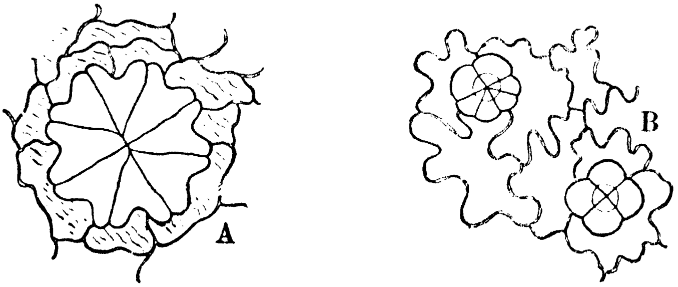


FIG. 175. *CAPRIFOLIACEAE*, A; *RUBIACEAE*, B

Hairs of: A, *Viburnum lentago* L.; B, *Carlemannia congesta* Hook. f.—By Solereder.

fibres; very sparse, except in *Nyssa*. Chambered crystalliferous strands sometimes present in *Nyssa*. Strands usually of 8 cells. **Rays** 2–4 cells wide; with some rays more than 1 mm. high, except in *Camptotheca*; uniseriates moderately numerous and composed of square and upright cells; about 8 rays per mm. in *Nyssa* and more than 12 in *Camptotheca* and *Davidia*; heterogeneous (Kribs's Type I), commonly with 4–10 marginal rows of square or upright cells and sometimes more, and with the biseriate parts not much wider tangentially than the uniseriate marginal rows. **Fibres** with bordered pits, the borders conspicuous in *Camptotheca* and *Davidia*, but flat and often inconspicuous in *Nyssa*; Solereder states that both simple and bordered pits occur in *Nyssa*. Walls usually moderately thin. Mean length 1·4–2·6 mm.

The wood of the 'knees' of the Tupelo Gum, *Nyssa aquatica* L., has been investigated by Penfound (1686), who found it to have more parenchyma and wider, shorter, and thinner-walled fibres than normal stem wood.

Root

Holm (991) has recorded the following facts about the root of *Nyssa sylvatica* Marsh. A homogeneous primary cortex and pith present in very young roots. All tissues from the epidermis to the endodermis of the mature roots replaced by thick, homogeneous cork enclosing a secondary cortex including thick-walled, pitted sclereids. Xylem of the mature root broad, composed of numerous, wide tracheids, thick-walled parenchyma, prosenchymatous elements, and rays 1–2 cells wide consisting of amyliferous cells. Secondary cortex containing cluster crystals of calcium oxalate and deposits of starch. The Tupelo Wood derived from the root of *Nyssa* consists largely of elements with very wide lumina.

Taxonomic Notes

Wangerin (2356) regarded *Camptotheca* and *Nyssa* as closely related to one another. He also drew attention to the somewhat isolated position of *Davidia* and suggested that this genus might be made the basis of a distinct family. Only wood from a young stem of *Davidia* was available for comparison, but this did not appear to differ significantly from that of *Nyssa*. Wangerin also expressed the view that there may be affinities between the Nyssaceae and Combretaceae, although he recognized the existence of considerable anatomical differences between the 2 families. The woods of these families differ in many important respects and there is little if any evidence of affinity. The woods of the Combretaceae are much more highly specialized than those of the Nyssaceae.

Economic Uses

The timber of *Nyssa* is well known to commerce under the names Tupelo Wood, e.g. *N. aquatica* L., and Black Gum, e.g. *N. sylvatica* Marsh, and is used for a variety of purposes such as boxes (veneer), joinery, and flooring.

The soft root wood of *Nyssa* has been used as a sponge in surgery on account of its absorbent properties.

GENERA DESCRIBED

FOR GENERAL ANATOMY AND WOOD STRUCTURE

Camptotheca, Davidia,* Nyssa.*

* Represented in the Kew slide collection.

LITERATURE

(i) *On General Anatomy*

Faure **673,** Holm **991,** Wangerin **2356.**

(ii) *On Wood Structure*

den Berger **182,** Brown, H. P. and Panshin **288, 289,** Hale **870,** Howard **1088,** Janssonius **1154,** Pearson and Brown **1679,** Penfound **1686,** Record **1818, 1843, 1851, 1867, 1868,** Record and Hess **1886,** Tang **2231.**

162. CAPRIFOLIACEAE

(FIG. 175 on p. 750; FIG. 176 on p. 754; FIG. 177 on p. 756)

SUMMARY

(i) GENERAL

A widely distributed family, consisting mostly of shrubs, but including a few, somewhat woody herbs. The leaf is usually dorsiventral. The **hairs** include glandular and non-glandular types. The **leaf-teeth** sometimes have a glandular function as well, and there are **extra-floral nectaries** on the petioles of *Sambucus* and *Viburnum*. The ranunculaceous **stomata** are, in most recorded instances, confined to the lower surface of the leaf. Rubiaceous stomata sometimes occur sporadically. The **petiole** exhibits a wide range of vascular structure in different genera. In the young stem the **cork** arises in the pericyclic region in some of the genera, but is superficial in others; the **pericycle** contains separate strands or a continuous ring of fibres or fibre-like elements with wide lumina. The **xylem** vessels tend to have scalariform perforation plates whilst the wood fibres are provided with bordered pits in most genera. **Crystals** are either solitary or clustered.

(ii) WOOD

Vessels small, exclusively solitary, ring-porous or semi-ring-porous, often with spiral thickening, perforation plates simple or simple and scalariform, intervascular pitting usually alternate, occasionally opposite or scalariform, pits to parenchyma similar; members of medium length to moderately long. **Parenchyma** typically apotracheal, diffuse, rarely scanty paratracheal. **Rays** usually 3–4 cells wide, heterogeneous. **Fibres** typically with distinctly bordered pits, often with spiral thickening, moderately short to moderately long. *Sambucus* differs from the above, having vessels grouped in a tangential pattern, moderately short vessel members, scanty paratracheal parenchyma, less markedly heterogeneous rays and fibres with simple pits.

LEAF

Usually dorsiventral, but palisade tissue poorly developed in certain species of *Triosteum* and *Viburnum*.

Hairs. A. Glandular. (i) Each having a uniseriate stalk of varying length, bearing a multicellular, ellipsoidal head, recorded in *Abelia*, *Diervilla*, *Dipelta*, *Leycesteria*, *Linnaea*, *Lonicera*, *Pentapyxis*, *Sambucus*, *Triosteum*, *Viburnum*. (ii) Peltate in *Diervilla*, *Symphoricarpus*. (iii) Absent from *Alseuosmia*.

B. Non-glandular. (i) Simple, unicellular of varying length recorded in *Lonicera*, *Sambucus*, *Triosteum*, *Viburnum*. (ii) Tufted or stellate, either sunk directly in the epidermis or provided with multicellular stalks, in *Viburnum*. (iii) Peltate in some species of *Viburnum* (Fig. 175 A).

Glandular leaf-teeth, which secrete resin and mucilage, occur at the terminations of veins. **Extra-floral nectaries,** situated on the petioles, recorded in species of *Sambucus* and *Viburnum*. According to Solereder the degree of undulation of the anticlinal walls of the cells of the **epidermis** is valuable for the identification of certain genera and species; e.g. almost straight in *Leycesteria*; very sinuous in *Triosteum*; undulating in a zigzag manner in *Viburnum opulus* Linn. Epidermis papillose on one or both surfaces of the leaf in several species of *Lonicera* and *Symphoricarpus*. **Stomata** confined to the lower surface in most species, but a few sometimes occur on the upper side as well in *Sambucus*; very frequently ranunculaceous in *Abelia*, *Alseuosmia*, *Diervilla*, *Dipelta*, *Leycesteria*, *Linnaea*, *Lonicera*, *Pentapyxis*, *Sambucus*, *Symphoricarpus*, *Triosteum*, *Viburnum*, but rubiaceous stomata also occur locally amongst the others in some of the above genera, notably *Viburnum*, e.g. according to Holm (1058) in *V. prunifolium* Linn. **Mesophyll** stated by Gundersen (845) to include a single layer of palisade cells except in *Diervilla*. Arm palisade cells recorded in *Sambucus* and *Viburnum*, and large intercellular spaces in the spongy mesophyll of *Linnaea borealis* Linn. Hagerup (863) has described the occurrence of smaller intercellular spaces, more strongly developed palisade tissue, and thicker walls to the epidermal cells in arctic than in more southern forms of *Linnaea borealis*. Large sclereids reported by Holm (1058) in the mesophyll of *Viburnum prunifolium* but not in other species of this genus. **Petiole** (Fig. 176 A–C), in transverse sections through the distal end, exhibiting a considerable range of structure. The following types noted in species examined at Kew. (i) A solitary, slightly crescentic, vascular strand in *Abelia grandiflora* Rehd. (Fig. 176 A), *Dipelta ventricosa* Hemsl., *Lonicera periclymenum* Linn., *Symphoricarpus albus* Blake, and *Viburnum opulus* Linn. (ii) An arc of 3 separate bundles in *Dipelta floribunda* Maxim (Fig. 176 C). (iii) An arc of 5 or more separate vascular strands in *Abelia triflora* R. Br. and *Sambucus nigra* Linn. (iv) A closed vascular cylinder, slightly flattened on the adaxial side, in *Viburnum tinus* Linn. (Fig. 176 B). Additional subsidiary strands in the wings observed in *Viburnum opulus* and *V. tinus*. An arc-shaped vascular strand also recorded by Solereder in *Lonicera flava* Sims, and a similar strand accompanied by 2 additional lateral bundles in *Leycesteria formosana* Wall. Gundersen's (845) observations on more than 50 species of Caprifoliaceae in general confirm the above statement concerning petiolar structure, and indicate that similar features are usually exhibited by closely related species. An arc of a few separate strands also recorded by the same author in *Alseuosmia* and *Kolkwitzia*. **Crystals** are, for the most part, either solitary or clustered. Cluster crystals were observed to occur in the cortical region of the petiole of all of the species of *Abelia*, *Dipelta*, *Lonicera*, *Symphoricarpus*, and *Viburnum* examined at Kew (see under 'Petiole' above). Crystal-sand present in

Sambucus. For a **developmental study** of the leaf of *Viburnum rufidulum* Raf. and *V. opulus* see Cross (509). For details of leaf structure in various species of *Linnaea*, *Lonicera*, *Sambucus*, *Symphoricarpus*, and *Viburnum* see Fischer's (686) thesis.

Axis

Young Stem (Fig. 176 D–E)

Outer walls of the cells of the **epidermis** seen to be strongly cuticularized in species of *Abelia* and *Viburnum* examined at Kew.

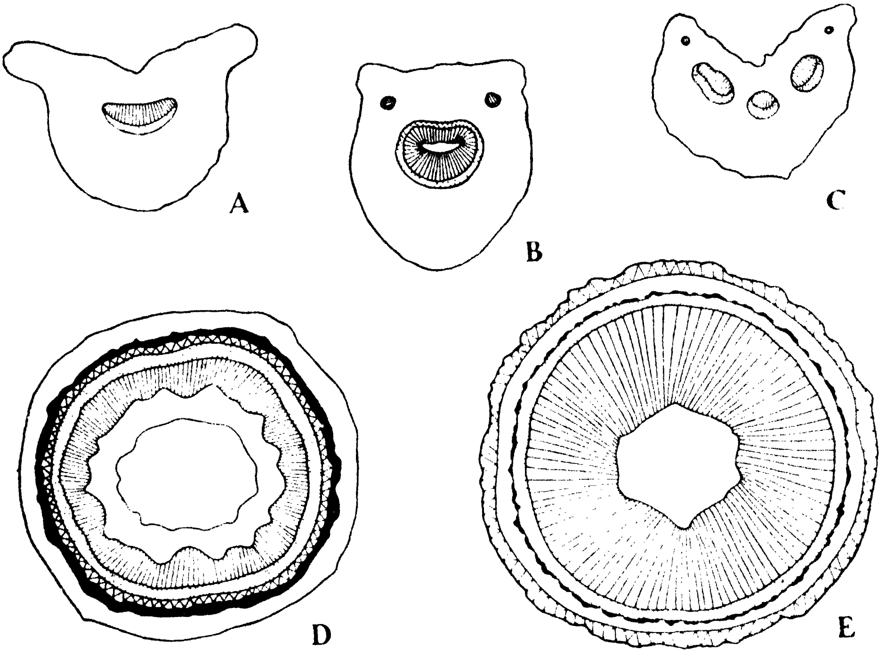


Fig. 176. *CAPRIFOLIACEAE*

A, *Abelia grandiflora* Rehd. Petiole × 33. B, *Viburnum tinus* Linn. Petiole × 15. C, *Dipelta floribunda* Maxim. Petiole × 15. D, *Symphoricarpus racemosus* Michx. Stem × 20. E, *Viburnum opulus* Linn. Stem × 8.

Cork usually arising in the pericyclic region in *Abelia*, *Diervilla*, *Dipelta*, *Leycesteria*, *Linnaea*, *Lonicera*, *Symphoricarpus* (Fig. 176 D), *Triosteum*; superficial in species of *Alseuosmia*, *Sambucus*, and *Viburnum*. Cork cells with wide lumina and either thin or thick walls in *Abelia*, *Diervilla*, *Lonicera*, *Sambucus*, *Symphoricarpus*, *Viburnum*. Primary **cortex** sometimes collenchymatous in *Sambucus* and *Viburnum*. **Pericycle** or inner part of the cortex nearly always containing wide fibres, or fibre-like elements with thin walls and very wide lumina, either in separate strands or in a ring. Elements of this kind noted at Kew in species of *Abelia*, *Diervilla*, *Dipelta*, *Lonicera*, *Symphoricarpus*. Further details concerning their occurrence and mode of development in these and other genera recorded by Cooper (462). Pericyclic fibres smaller in diameter and thick-walled in *Sambucus* and *Viburnum*. **Phloem** seen to include thick-walled fibres in species of *Dipelta*, *Lonicera*, and *Symphoricarpus*. A few groups of sclerosed elements recorded by Holm (1038) in the phloem of *Sambucus canadensis* Linn. **Xylem** in the form of a continuous cylinder traversed by narrow rays in the species examined at Kew; including vessels, which exhibited scalariform perforation plates in the material examined (see also 'Wood'). Fibres with bordered pits except in *Alseuosmia* and *Sambucus*. **Pith** heterogeneous in *Abelia, Diervilla, Lonicera, Symphoricarpus*; very large and consisting of dead cells, except in young actively growing shoots, in *Sambucus*. **Secretory elements.** Sacs with brown, gelatinous, tanniniferous contents present in the peripheral part of the pith and in the pericycle of *Sambucus*. Secretory cells, with unidentified contents, observed in the cortex of a few species of *Abelia, Diervilla, Dipelta*, and in the unlignified tissues generally in *Viburnum opulus* and *V. tinus*. Cluster **crystals** observed at Kew in species of *Abelia, Diervilla, Dipelta, Lonicera, Symphoricarpus, Viburnum*, but not in *Sambucus*; crystal-sand seen in the cortex and phloem of *Sambucus nigra* L. and in the rhizome of *S. ebulus* Linn.

WOOD (Fig. 177)

Vessels small (mean tangential diameter less than 100 μ) and often very small (less than 50 μ), e.g. in *Abelia, Dipelta*, and *Symphoricarpus*, exclusively solitary, apart from tangential pairs due to overlapping ends, except in *Sambucus*, in which short radial multiples and clusters are numerous (Fig. 177 C); with a tangential pattern in *Sambucus*, sometimes pronounced, e.g. in *S. glauca* Nutt.; typically more than 30 per sq. mm. and often more than 100, e.g. in some species of *Abelia, Dipelta*, and *Symphoricarpus*; typically ring-porous or semi-ring-porous; with faint spiral thickening in some species of *Abelia* (1851), *Dipelta, Leycesteria, Lonicera, Sambucus* (1851), *Symphoricarpus* (1851), and *Viburnum*. Perforations simple in *Lonicera, Sambucus*, and *Symphoricarpus*, though sometimes accompanied by occasional scalariform plates in the neighbourhood of the primary wood; perforation plates exclusively or predominantly scalariform in *Abelia, Alseuosmia* (2158), *Diervilla, Dipelta, Leycesteria*, and *Viburnum*; with more than 20 bars in *Diervilla* and *Viburnum*. Intervascular pitting alternate, medium-sized to moderately small, occasionally opposite or scalariform in *Leycesteria* and *Symphoricarpus*; pits to ray cells similar to the intervascular pitting. The sieve-like structures described by Janssonius (1154) in *Viburnum* are not, according to Bailey (78), true vestured pits. Tyloses sometimes abundant in *Sambucus*. Mean member length 0·3–1·2 mm., shortest in *Lonicera* and *Sambucus*. **Parenchyma** rather sparse; apotracheal, scattered among the fibres (diffuse) in *Abelia, Diervilla, Dipelta, Leycesteria, Symphoricarpus*, and *Viburnum* (Fig. 177 F); paratracheal, very scanty, as a few cells round the vessels in *Lonicera* and *Sambucus* (Fig. 177 C and G); often in narrow terminal bands in *Sambucus*. Strands usually of 8 cells, but commonly of 2–4 cells in *Sambucus*. **Rays** usually up to 3 or 4 cells wide, up to 5 cells in some species of *Abelia* and *Lonicera*, and seldom more than 2 cells wide in some species of *Viburnum*; commonly about 1 mm. high, with fused rays higher; less than 1 mm. high in *Sambucus*; uniseriates composed entirely of square to upright cells, typically numerous and moderately high, but fewer and often only 1–3 cells high in *Sambucus*; typically 11–19 rays per mm., but sometimes fewer in *Sambucus*; heterogeneous (Kribs's Types I and II A), usually with 1–4 marginal rows of square to upright cells, often with more than 10 rows in *Diervilla* and *Leycesteria*; composed entirely of square to upright cells in *Dipelta* (Fig. 177 E) and sometimes with very few truly procumbent cells in *Lonicera*; sheath cells present in *Leycesteria* and *Sambucus*. **Fibres** typically with distinctly bordered pits that are sometimes slightly less numerous on the tangential than on the radial walls, but with small, simple pits in *Alseuosmia* (2158) and *Sambucus*, the pits in *Sambucus*

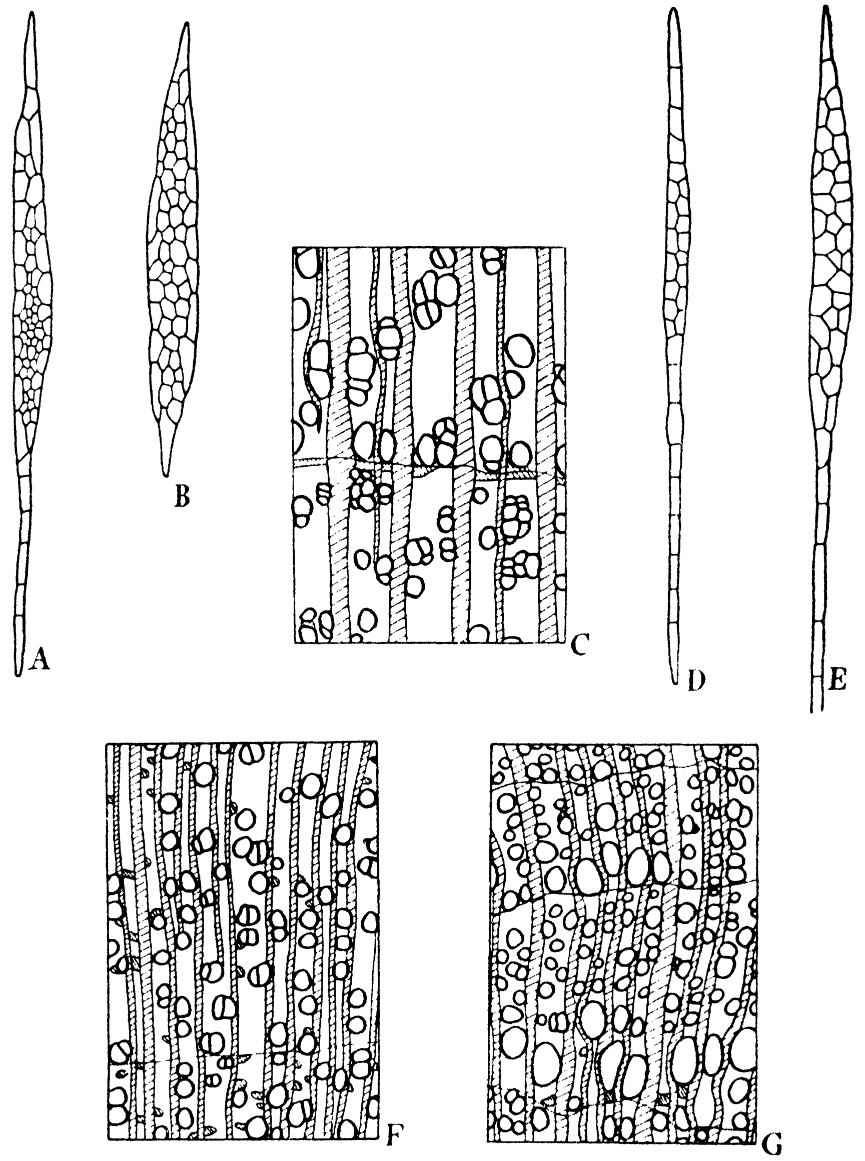


Fig. 177. *CAPRIFOLIACEAE*
A, *Leycesteria formosa* Wall. B, *Sambucus callicarpa* Greene. C, *S. nigra* Linn. D, *Viburnum opulus* Linn. E, *Dipelta yunnanensis* Franch. F, *Diervilla subsessilis* Bailey. G, *Lonicera* sp.

almost entirely limited to the radial walls; reported (2158) to be septate in *Alseuosmia*; walls moderately thin. Spiral thickening present in *Abelia*, *Leycesteria*, *Lonicera*, *Symphoricarpus*, and *Viburnum*. Mean length 0·8–1·8 mm. **Growth rings.** The periodicity of cambial activity in *Sambucus* has been investigated in Java by Coster (481).

ROOT

The following information has been recorded by Gundersen (845). **Cortex** containing fibres in *Abelia*, *Linnaea*, and *Sambucus*. Principal roots diarch; smaller and adventitious roots often containing 3 or 4 bundles.

TAXONOMIC NOTES

Sambucus is distinguished from the other genera in this family by the occurrence of crystal-sand and the presence in the stem of narrow, thick-walled, pericyclic fibres and a large pith. It also differs from the rest of the family in having compound leaves. Its secondary xylem is more highly specialized than that of the other genera and differs in several respects. The taxonomic position of the genus has been much discussed and it has even been suggested that it should be assigned to a separate family, the Sambucaceae.

Sax and Kribs (2002) state that there is no relation between either number or size of chromosomes and vascular specialization of the genera.

ECONOMIC USES

The Elder Tree (*Sambucus nigra* Linn.) yields the following products. Pith is used by watch- and instrument-makers for cleaning fine pivots in delicate machinery, and for embedding botanical material for cutting sections. The berries and flowers are used in the preparation of medicinal concoctions and beverages. The hard timber can be employed for making certain grades of charcoal and for pegwood which is used by instrument-makers. It can also be used for making small brush handles, mathematical instruments, and for other miscellaneous purposes. All of the above items were prepared in Britain from *Sambucus nigra* during the Second World War. Various species of *Lonicera* and *Viburnum* are cultivated for ornamental purposes.

An extract of the root bark of the Black Haw (*Viburnum prunifolium* Linn.) is occasionally used for various medicinal purposes. The bark is characterized microscopically, according to the British Pharmaceutical Codex, by ovoid masses of stone cells; the absence of phloem fibres; starch grains up to 15 μ in diameter; abundant cluster crystals of calcium oxalate. According to Holm (1058) it contains a yellow resin with a bitter taste. 'Cramp Bark' is derived from *Viburnum alnifolium* Marsh. For the anatomy of this and other commercial *Viburnum* barks see Viehover *et al.* (2332). According to Unger (2312) the rhizome of *Sambucus ebulus* Linn. is very much like that of *Atropa belladonna* (Family Solanaceae). *Sambucus* may be distinguished by the massive secondary cortex, a dark orange secretion in the peripheral cells of the pith, and the presence of crystal-sand in the cortex and pith, in contradistinction to *Atropa belladonna* where crystal-sand occurs in the ray cells as well (see also under Solanaceae, p. 974). The family produces no important commercial woods.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Abelia,* Alseuosmia, Diervilla,* Dipelta,* Kolkwitzia, Leycesteria, Linnaea, Lonicera,* Pentapyxis, Sambucus,* Symphoricarpus,* Triosteum, Viburnum.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Abelia, (Alseuosmia), Diervilla, Dipelta, Leycesteria, Lonicera, Sambucus, Symphoricarpus, and Viburnum.

LITERATURE

(i) *On General Anatomy*

Bowman **250**, Burgess **314**, Cooper **462**, Cross **509**, Esau **661**, Ewing and Clevenger **668**, Fischer **686**, Gundersen **845**, Hagerup **863**, Holm **1038**, **1058**, Noelli **1603**, Unger **2312**, Viehover **2332**, Wirth **2448**, Youngken and Munch **2498**.

(ii) *On Wood Structure*

Bailey **78**, den Berger **182**, Burgerstein **312**, Chalk and Chattaway **358**, Coster **481**, Greguss **2522**, Howard **1088**, Janssonius **1154**, Kanehira **1206**, **1209**, Nicoloff **1593**, Record **1783**, **1800**, **1843**, **1851**, Record and Hess **1886**, Sax and Kribs **2002**, Thompson **2254**, Yamabayashi **2478**.

163. ADOXACEAE

SUMMARY

The sole representative of the family is *Adoxa moschatellina* L., a small herb with a creeping rhizome which occurs in the northern hemisphere. A monograph concerning the species, which includes an account of its anatomy, has been published by Stürm (2214), who compares it with *Sambucus* and points out the considerable differences in the anatomical structure of the 2 genera. The following description is based mainly on Stürm's monograph.

LEAF

Dorsiventral. Deciduous, tanniniferous, secretory **hairs** present on the young leaf. **Epidermis,** on both surfaces, with sinuous anticlinal walls; papillose on the upper side of the central part of the lamina. Groups of **hydathodes** present on the upper side of the leaf segments. **Stomata** ranunculaceous; confined to the lower surface. **Mesophyll** including cubical and arm-palisade cells and 4 or 5 layers of spongy mesophyll. **Vascular system** consisting of 3 bundles united at the base of the leaf.

AXIS

FLOWER STALK

Usually containing 2 well-developed **vascular bundles** serving to supply the cauline leaves and 2 smaller ones leading to the flowers; exceptionally provided with 3 or 5 bundles. Bundles supported by collenchyma when young, and by prosenchymatous elements when older; first-formed xylem including spirally thickened vessels, scalariform pitting developing in the later vessels. **Starch** abundant in the parenchymatous tissues. **Crystals.** Sphaerites, previously recorded by Eichinger around the vascular bundles, not observed by Stürm.

RHIZOME

Exhibiting swellings at intervals along its length. Sections through a fully differentiated rhizome show the following structure. **Epidermis** composed of cells elongated in the same direction as the axis. **Stomata** slightly raised above the general level of the epidermis. **Cortex** constituting the greater part of the rhizome; composed of relatively large, amyliferous cells, those towards the centre of the axis smaller and sometimes pitted. **Endodermis** not always well defined, composed of cells with casparian thickenings. Contrary to the statement of earlier workers a **pericycle** was not observed by Stürm, who noted dorsal and ventral strands of phloem fibres. **Vascular system** consisting of dorsal and ventral, flattened, collateral strands, with pith cells in the central and lateral positions. Xylem including vessels with spiral thickening when young, but scalariform pits arising later on. **Crystals** and **secretory cells** absent.

ROOT

Similar in structure to the rhizome. Transverse sections through the fully matured root exhibit the following structure. **Epidermis** composed of longitudinally elongated cells with pitted walls, the outer and radial walls being suberized. **Cortex** parenchymatous, amyliferous, but narrower than that of the rhizome. **Endodermis** similar to that of the rhizome. **Pericycle** composed of small amyliferous cells. **Xylem** in 3 strands, separated in the autumn by broad rays; vessels in young roots spirally thickened, those in older roots have scalariform pits. **Pith** containing starch.

TAXONOMIC NOTES

The taxonomic position of *Adoxa* has been much disputed. The various expressions of opinion on this subject have been summarized and reviewed by Stürm (l.c.) who considers that the genus is the sole member of a distinct family of which the affinities are unknown.

GENUS DESCRIBED

Adoxa.*

* Represented in the Kew slide collection.

LITERATURE

On General Anatomy
Stürm **2214.**

164. RUBIACEAE

(FIG. 175 on p. 750; FIG. 178 on p. 760; FIG. 179 on p. 764; FIG. 180 on p. 766; FIG. 181 on p. 768)

SUMMARY

(i) GENERAL

A large family exhibiting a wide range of habit, including trees, shrubs, and herbs. The family is widely distributed but mainly tropical. The leaf is usually dorsiventral, but centric or homogeneous structure occurs in a few species. The **hairs** are unicellular, uniseriate, tufted, and occasionally peltate. The unicellular trichomes of the Guetardeae have crystals embedded in the thickened walls. The leaf surface is, in some instances, provided with a superficial **vein-like network** containing spiral tracheids or fibres. The **stomata,** nearly always confined to the lower surface, are typically rubiaceous. The **petiole,** in transverse sections through the distal end, besides accessory strands towards the wings, exhibits a crescent-shaped or cylindrical median bundle, occasionally enclosing a few small 'medullary' strands. In the stem the **cork** arises superficially in some genera but is more deep-seated in others, and the **pericycle** includes a variable amount of sclerenchyma. **Anomalous secondary thickening,** including the development of furrowed xylem or of secondary strands of xylem and phloem, has been recorded in a few genera. **Secretory elements** include secretory cavities of various kinds, whilst secretory cells are also common. **Crystals** are abundant and include crystal-sand, raphides, clustered crystals, styloids, and other acicular types. The type of crystal is of value in the identification of genera and species. *Myrmecodia* is of interest on account of the ant **domatia** which form a network of chambers in its tuberous roots. Cavities, sometimes stated to be domatia for small organisms, have also been recorded on the leaves of a few genera, including *Coffea.* Certain species of *Pavetta* and other genera bear bacterial nodules on the leaves in which atmospheric nitrogen is fixed.

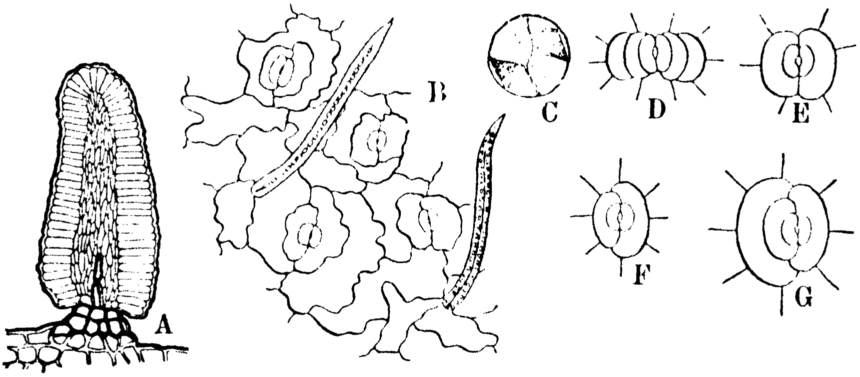


FIG. 178. RUBIACEAE

A, Glandular shaggy hair of *Isertia coccinea* Vahl. B, C, Crystal-hairs on the lower side of the leaf of *Malanea macrophylla* Bartl. C, crystal-hair in transverse section. D–G, Types of stomata.—By Solereder.

(ii) WOOD

Vessels typically small, but medium-sized in some genera, exclusively solitary or nearly so in about half the genera, with numerous small multiples in the others or with multiples of 4 or more cells in a few genera; typically numerous, rarely ring-porous, perforations simple, intervascular pitting alternate and typically small to minute, pits to parenchyma similar in size and shape; vestured; members of medium length to very long, usually of medium length. **Parenchyma** typically apotracheal in species with non-septate fibres, and absent from those with septate fibres, though with some exceptions; the apotracheal parenchyma usually as scattered cells tending to form short uniseriate lines, in broad bands in a few genera; scanty paratracheal parenchyma present in a few genera with either septate or non-septate fibres; raphides present in a few genera. **Rays** most typically narrow, up to 2–3 cells wide, with 4 to many marginal rows of upright cells and with numerous uniseriate rays; wholly uniseriate in several genera and up to 8–10 cells wide in a few species; heterogeneous, varying from rays composed entirely of square or upright cells to rays with only 1 or 2 marginal rows of square or upright cells; crystal-sand and raphides present in a few genera. **Fibres** (*a*) in about 75 per cent. of the genera non-septate, pits with small to very distinct borders; (*b*) in the other genera, septate, with simple or slightly bordered pits. Very short to moderately long, usually of medium length.

LEAF

Dorsiventral in nearly all of the species examined, but centric in *Asperula cynanchica* Linn.; homogeneous in *Borreria verticillata* G. F. W. Meyer and wholly composed of short palisade cells in *Oldenlandia aspera* DC. according to Sabnis (1977). **Hairs** unicellular, uniseriate, tufted, or rarely peltate. Unicellular hairs sometimes curved at the apex, e.g. in species of *Asperula*, *Cephalanthus*, *Chiococca*, *Galium*, *Gardenia*, *Ixora*, *Randia*, and probably other genera. Unicellular, thick-walled trichomes, with numerous small crystals embedded in the walls, occur in *Guettarda*, *Malanea* (Fig. 178 B–C), and allied genera. Uniseriate hairs noted or recorded in species of *Cephaelis*, *Coffea*, *Luculia*, *Manettia*, *Pentas*, and almost certainly occurring in other genera as well. Peltate hairs recorded in *Carlemannia* (Fig. 175 B) and *Silvianthus*. Glandular hairs unknown, apart from shaggy hairs on the stipules, e.g. in *Isertia* (Fig. 178 A), from which the copious secretion of mucilaginous and resinous material often coats the adjacent leaves. Cells of the **epidermis** with straight or sinuous anticlinal walls; those on the upper surface papillose above the larger veins in species of *Galium*. Spiral tracheids or sclerenchymatous fibres form a **superficial network,** partly associated with the veins, especially on the abaxial surface of the leaf, in *Chomelia*, *Macrocnemum*, *Pentagonia*. A similar network, but apparently devoid of tracheids, also recorded in *Hippotis*, *Pauridiantha*, *Stilpnophyllum*, *Tammsia*. **Hypoderm** recorded in species of *Chasalia*, *Cinchona*, *Condaminea*, *Coprosma*, *Craterispermum*, *Gaertnera*, *Hydnophytum*, *Leucodon*, *Myrmecodia*, *Pagamea*, *Psychotria* (epiphytic species), *Rustia*, *Scyphiphora*. **Stomata** nearly always confined to the lower surface; recorded on the upper surface as well in *Coprosma petriei* Cheesem. and by Fischer (686) in a few species of *Asperula*, *Galium*, *Litorella*, *Rubia*; usually rubiaceous (Fig. 178 D–G), but the arrangement of the subsidiary cells varying somewhat in different genera and species. Stomata localized in groups of 2–4 in *Pagamea*, their distribution sometimes apparent to the naked eye or under a lens as circumscribed areas. **Mesophyll** containing sclerenchymatous idioblasts in species of *Burchellia*, *Chomelia*, *Coffea*. **Midrib,** according to Sabnis (1977), vertically transcurrent by collenchyma in *Oldenlandia aspera* DC. Vascular bundles of the **veins** in most members of the Galieae investigated by Fischer (686) surrounded by an endodermis with casparian thickenings.

Petiole (Fig. 179), in transverse sections through the distal end, usually shield-shaped and commonly with more or less well-developed wings;

exhibiting a large, variously shaped median vascular strand, nearly always accompanied by smaller accessory bundles towards the wings. Main vascular strand exhibiting the following structure. (i) A shallow, open arc in *Chiococca bermudiana* S. Brown, *Hoffmannia* sp., *Manettia inflata* Sprague (Fig. 179 I), *Pentas coccinea* Stapf, *Posoqueria latifolia* Roem. et Schult. (ii) Similar to (i) but arc usually deeper and with its ends strongly incurved in *Canephora* spp. (Wernham 2415), *Cephalanthus occidentalis* Linn., *Emmenopterys henryi* Oliv. (Fig. 179 G), *Exostema longifolia* Roem. et Schult., *Luculia gratissima* Sweet (Fig. 179 F), *Mitriostigma axillare* Hochst. (ends somewhat outwardly curved) (Fig. 179 K), *Randia dumetorum* Lam., *R. micrantha* K. Schum. (iii) Cylindrical, but not usually including 'medullary' strands in *Cephaelis ipecacuanha* (Brot.) A. Rich (concave towards the adaxial surface) (Fig. 179 D), *Coffea arabica* Linn., *C. liberica* Hiern, *Pavetta caffra* Linn. (Fig. 179 C), *P. obovata* E. Mey. According to Mariani (1440) the median strand is closed at the distal end in most species of *Coffea*, and there are occasionally 1 or 2 'medullary' strands within the ring. Main vascular strand concave throughout its length in *C. jasminoides* Welw., *C. wightiana* Wall. (iv) Deeply crescentic, but with 2 rows of accessory strands between the ends of the crescent in *Cinchona succirubra* Pav. (Fig. 179 H). (v) Crescent-shaped, but with a few small accessory strands in the concavity in *Psychotria emetica* Linn. (vi) Cylindrical but enclosing some accessory 'medullary' strands in the hollow centre in '*Gardenia intermedia*' and *G. spathulifolia* Stapf et Hutchinson (Fig. 179 B) (see also *Coffea* under (iii) above). (vii) A shallow crescent with a small, hollow, cylindrical and 2 solid accessory strands between the ends of the crescent in *Sarcocephalus esculentus* Afzel. (Fig. 179 A).

Secretory elements. Schizogenous secretory cavities, containing resinous material and appearing as transparent dots in the leaf, recorded in *Rustia* and *Tresanthera*. Secretory cells of various types also known to occur. (i) Large resiniferous cells in the lower epidermis appear as pellucid dots in species of *Anthospermum* and *Rubia*; similar cells also recorded in the upper epidermis of species of *Galium* and *Nenax* as well as in the mesophyll of *Dirichletia* and *Polysphaeria*. (ii) Secretory cells with brown contents occur as (*a*) groups of branched elements in the mesophyll of *Phyllis*; (*b*) dilated cells, especially in the palisade tissue of species of *Gardenia*, *Plectronia*, *Randia*, *Vangueria*; (*c*) in the veins of *Pyrostria*. (iii) Short mucilage cells present in the mesophyll of a few species of *Holocarpa* and *Pentanisia*. (iv) Elongated mucilage sacs, situated externally to the phloem in the petiole of *Cinchona* (at one time described as laticiferous vessels), and *Henriquezia*, as well as in the veins of *Mussaenda*. Secretory cells with unidentified contents noted at Kew in the ground tissue and sometimes the phloem of the petiole in species of *Cephaelis*, *Cephalanthus*, *Coffea*, *Emmenopterys*, *Exostema*, *Gardenia*, *Hoffmannia*, *Ixora*, *Luculia*, *Mitriostigma*, *Pentas*, *Randia*, *Rondeletia*, *Sarcocephalus*, *Vangueria*. Tanniniferous cells described as abundant in *Canephora* by Wernham (2415), in *Coffea* by Mariani (1440), and in *Spermacoce hispida* Linn. by Sabnis (1977). A substance related to phytosterin said by Nicolas (1592) to be secreted from sub-terminal groups of cells in the leaves of many species of *Galium*, including *G. verum* Linn.

Crystals in both leaf and stem occur in the form of raphides (usually in elongated sacs, sometimes containing mucilage as well), crystal-sand (in sacs sometimes recognizable by naked eye as bright dots in the leaf or as white powder in the cortex), and ordinary clustered types. Large rhombohedra rare. Crystal distribution helpful in identifying genera.

I. Crystal-sand, either alone or accompanied by clustered crystals, in *Adina*, *Alberta*, *Alibertia*, *Alseis*, *Amaioua*, *Amaralia* (in branched sacs), *Anthocephalus*, *Antirrhoea*, *Basanacantha*, *Bathysa*, *Bertiera*, *Bikkia*, *Bobea*, *Bothriospora*, *Burchellia*, *Calycophyllum*, *Canephora*, *Cascarilla*, *Cephalanthus*, *Chimarrhis*, *Chiococca*, *Chione*, *Chomelia*, *Cinchona*, *Coffea*, *Condaminea*, *Corynanthe*, *Coutarea*, *Diplospora*, *Dolicholobium*, *Duroia*, *Erithalis*, *Exostema*, *Ferdinandusa*, *Feretia*, *Fernelia*, *Galiniera*, *Genipa*, *Gonzalea*, *Guettarda*, *Heinsia*, *Henriquezia*, *Hymenodictyon*, *Hyptianthera*, *Jackia*, *Ladenbergia*, *Laugeria*, *Luculia*, *Machaonia*, *Macrocnemum*, *Malanea*, *Mitriostigma*, *Molopanthera*, *Mussaenda*, *Mussaendopsis*, *Nauclea*, *Nematostylis*, *Pavetta*, *Pentagonia*, *Petunga*, *Pinckneya*, *Pogonopus*, *Polysphaeria*, *Portlandia*, *Posoqueria*, *Remijia*, *Rhabdostigma*, *Rondeletia*, *Rustia*, *Sabicea*, *Sarcocephalus*, *Scolosanthes*, *Sickingia*, *Sipanea*, *Sommera*, *Stephegyne*, *Strumpfia*, *Timonius*, *Tocoyena*, *Tricalysia*, *Uncaria*, *Villaria*, *Warscewiczia*, *Webera*, *Wendlandia*, *Zuccarinia*.

II. Raphides, either alone or accompanied by clustered crystals, in *Adenosacme*, *Anthospermum*, *Argostemma*, *Asperula*, *Bouvardia*, *Callipeltis*, *Carpacoce*, *Cephaelis*, *Chasalia*, *Coccocypselum*, *Coffea*, *Coprosma*, *Coptosapelta*, *Coussarea*, *Crucianella*, *Cruckshankia*, *Crusea*, *Damnacanthus*, *Danais*, *Declieuxia*, *Dentella*, *Deppea*, *Diodia*, *Dirichletia*, *Emmeorhiza*, *Ernodea*, *Faramea*, *Gaertnera*, *Gaillonia*, *Galium*, *Galopina*, *Hamelia*, *Hamiltonia*, *Hedyotis*, *Hemidiodia*, *Heterophyllaea*, *Hillia*, *Hindsia*, *Hoffmannia*, *Holocarpa*, *Houstonia*, *Hydnophytum*, *Hydrophylax*, *Hymenopogon*, *Kelloggia*, *Knoxia*, *Lasianthus*, *Lecananthus*, *Leptodermis*, *Manettia*, *Mapouria*, *Mericarpaea*, *Mitchella*, *Mitracarpum*, *Morinda*. *Myrioneuron*, *Myrmecodia*, *Nenax*, *Nertera*, *Ocrodon*, *Oldenlandia*, *Ophiorrhiza*, *Oreopolus*, *Otiophora*, *Otomeria*, *Paederia*, *Pagamea*, *Palicourea*, *Pentanisia*, *Pentas*, *Pentodon*, *Perama*, *Phyllis*, *Plocama*, *Polyura*, *Pomax*, *Psychotria*, *Psyllocarpus*, *Putoria*, *Relbunium*, *Richardsonia*, *Rubia*, *Rudgea*, *Saprosma*, *Schradera*, *Serissa*, *Sherardia*, *Spermacoce*, *Spiradiclis*, *Staelia*, *Triodon*, *Urophyllum*, *Vaillantia*.

III. Clustered crystals alone or together with small acicular crystals in *Catesbaea*, *Crossopteryx*, *Fadogia*, *Gardenia*, *Greenea*, *Isertia*, *Ixora*, *Myonima*, *Plectronia*, *Pyrostria*, *Randia*, *Rondeletia*, *Sphinctanthus*, *Vangueria*.

IV. Small acicular crystals, either alone or accompanied by other kinds of crystal in *Aulacocalyx*, *Chasalia*, *Fadogia*, *Gaertnera*, *Lecananthus*, *Mussaenda*, *Plectronia*, *Randia*, *Schradera*, *Vangueria*.

V. No crystals observed in *Limnosipanea* and *Retiniphyllum*. Sphaerocrystalline masses, believed to consist of **hesperidin,** recorded in spirit material and in glycerine preparations of *Galium*.

BACTERIAL NODULES AND 'DOMATIA'

Bacterial nodules have been recorded by several authors on the leaves of *Chomelia asiatica* Wall., various species of *Pavetta*, and *Psychotria bacteriophila* Val. The information concerning these has been summarized by Boodle (236) from whose paper the following statement is quoted:

'It appears that the presence of bacterial nodules is a constant feature of those

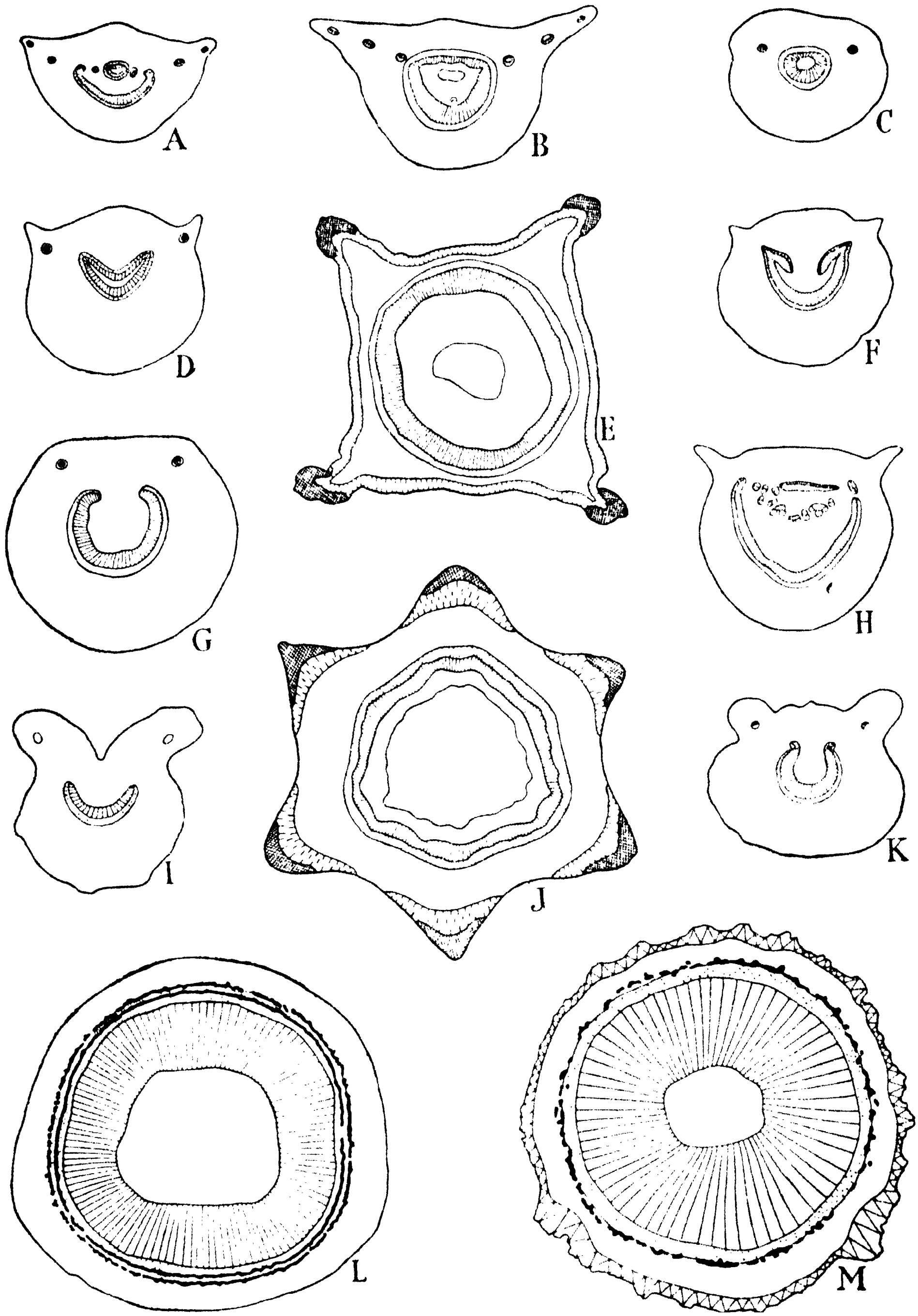


FIG. 179. *RUBIACEAE*

A, *Sarcocephalus esculentus* Afzel. Petiole × 8. B, *Gardenia spathulifolia* Stapf et Hutch. Petiole × 20. C, *Pavetta caffra* Linn. Petiole × 19. D, *Cephaelis ipecacuanha* (Brot.) A. Rich. Petiole × 12. E, *Galium aparine* Linn. Stem × 19. F, *Luculia gratissima* Sweet. Petiole × 8. G, *Emmenopterys henryi* Oliv. Petiole × 8. H, *Cinchona succirubra* Pav. Petiole × 8. I, *Manettia inflata* Sprague. Petiole × 12. J, *Rubia tinctorum* Linn. Stem × 15. K, *Mitriostigma axillare* Hochst. Petiole × 15. L, *Coffea liberica* Hiern. Stem × 15. M, *Rondeletia cordata* Benth. Stem × 14.

species in which they have been found, and the explanation of this is supplied by Von Faber, who demonstrated the occurrence of bacteria in the seed, between the embryo and the endosperm. The seedling is therefore infected from the first. The bacteria establish themselves in the leaf-buds, in a gummy secretion within the stipular sheath, and infect the young leaves in the bud, entering them through certain stomata, which are formed at a rather early stage and are connected with secretory cavities in the mesophyll. In the region of each point of entry of the bacteria, the mesophyll develops into a special enlarged lacunar tissue, the intercellular spaces of which become occupied by the bacteria, the leaf becoming locally thickened owing to the special growth of mesophyll tissue.'

Boodle also records that the bacteria have been shown to be capable of fixing atmospheric nitrogen, and points out that the leaves of some of the species are much valued as green manure in India and Ceylon. Somewhat similar bacterial cavities also occur at the leaf margins of *Ardisia crispa* A. DC. (see 'Myrsinaceae').

Cavities believed to be 'domatia', noted by Mariani (1440), in the angles between the junctions of the secondary veins with the midrib in 25 species of *Coffea*. Somewhat similar cavities ('Krypten'), of unproved physiological significance, recorded by Lakon (1313) in the leaves of *Coprosma baueri* Endlicher, and in the same species by Shirley and Lambert (2092). Solereder (2162) has stated that the somewhat similar 'glands' of *Heterophyllaea pustulata* Hook. f. are not bacterial cavities.

AXIS

YOUNG STEM

(i) Galieae (Fig. 179 E and J)

The Galieae, as represented by species of *Asperula*, *Galium*, and *Rubia* in the Kew slide collection, exhibit the following structure. Stem polygonal with collenchymatous ribs. **Cork** not developed in the material examined. **Endodermis** well defined, usually provided with casparian thickenings. **Pericycle** devoid of sclerenchyma. **Xylem** forming a very narrow but continuous cylinder and including poorly differentiated vessels of very small diameter. **Crystals** present exclusively in the form of raphides.

(ii) Genera not included in the Galieae (Fig. 179 L–M)

Corrugated stems of *Canthium* spp. described by Francis (708). Corrugations first apparent in stems of *C. latifolium* F. v. M. when 1 inch in diameter. Medullary rays much broader in the depressions between the corrugations than elsewhere. Stem of *Spermacoce hispida* Linn. described by Sabnis (1977) as ribbed, with assimilatory tissue extending into the ribs. **Cork** arising in the epidermis, sub-epidermis, or outer part of the cortex of species of *Burchellia*, *Cephaelis*, *Cephalanthus*, *Chiococca*, *Chione*, *Cinchona*, *Emmenopterys*, *Exostema*, *Faramea*, *Gardenia*, *Genipa*, *Guettarda*, *Ixora*, *Laugeria*, *Luculia*, *Pentas*, *Pinckneya*, *Randia* (pro parte), *Rondeletia*, *Rudgea*, *Sarcocephalus*, *Sipanea*, *Strumpfia*, *Vangueria*; arising towards the inside of the cortex or even more deeply seated in some species of *Bouvardia*, *Coffea*, *Coprosma*, *Leptodermis*, *Paederia*, *Pagamea*, *Pavetta*, *Pentas*, *Phyllis*, *Psychotria*, *Putoria*, *Randia* (pro parte), *Rubia*, *Serissa*. Cork exhibiting a tier-like structure in *Coffea* and *Pavetta*. Walls of the cork cells varying considerably in thickness in different genera and species. Primary **cortex** collenchymatous in *Cinchona* and *Ixora*; containing scattered sclerotic elements in species of *Cascarilla*, *Cinchona*, *Coffea*. Centric cortical bundles recorded in *Sickingia*. **Endodermis** well defined and provided with casparian thickenings in species of *Cephaelis*, *Hoffmannia*, and *Manettia* examined at Kew. **Pericycle** containing a variable amount of sclerenchyma in different genera and species. Isolated bundles of fibres recorded in this position by Solereder in species of *Chimarrhis*, *Faramea*, *Guettarda*, *Hamelia*, *Hyptianthera*, *Ixora*, *Morinda*, *Mussaenda*,

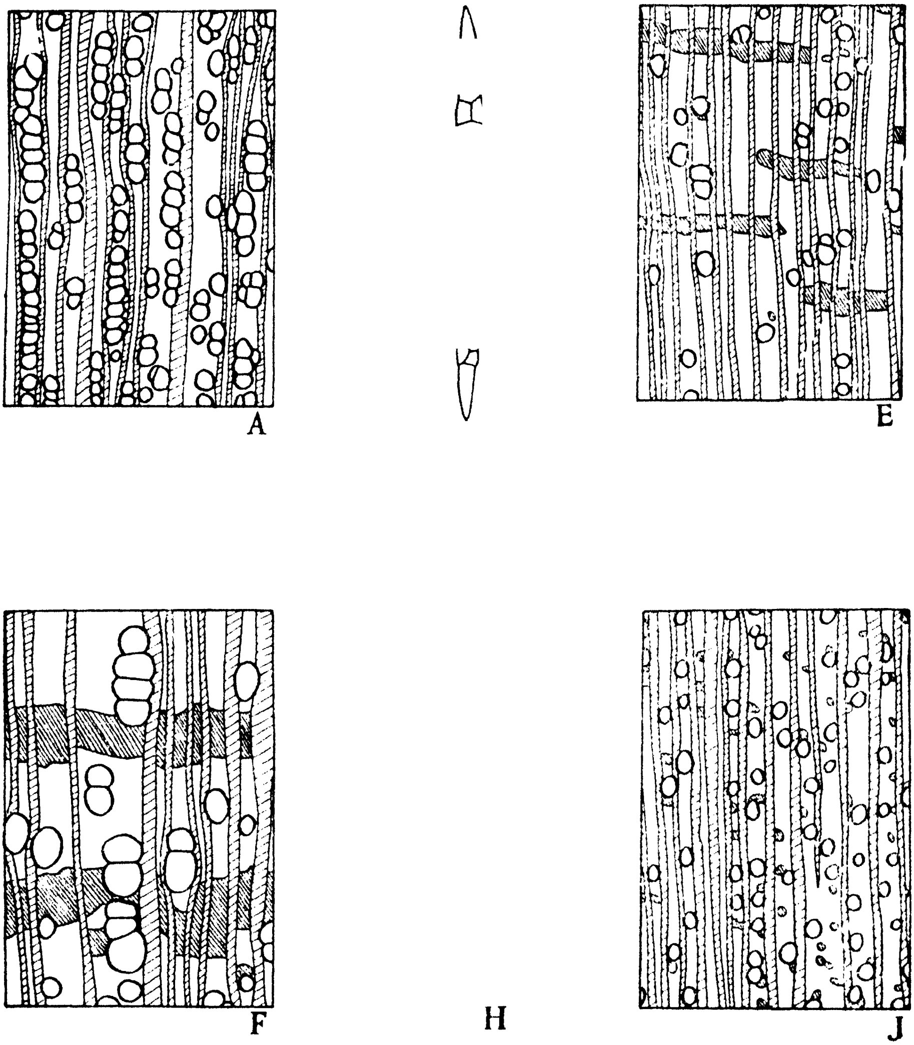


Fig. 180. *RUBIACEAE*

A, *Uragoga peduncularis* (Salisb.) K. Schum. B, *Vangueriopsis discolor* Robyns. C, *Adina cordifolia* Benth. et Hook. D, *Aulacocalyx jasminiflora* Hook. f. E, *Gaertnera cooperi* Hutch. et Moss. F, *Craterispermum cerinanthum* Hiern. G, *Coutarea hexandra* J. R. Johnston. H, *Mussaendopsis beccariana* Baill. I, *Gardenia latifolia* (Soland.) A. H. K. J, *G. latifolia* (Soland.) A. H. K.

Paederia, *Pavetta*, *Plectronia*, *Posoqueria*, *Psathura*, *Psychotria*, *Urophyllum*, *Vangueria*, and a continuous ring of thick-walled fibres in *Canephora* by Wernham (2415). Pericyclic sclerenchyma absent from species of *Cephaelis*, *Hoffmannia*, and *Manettia* examined at Kew. Fibres observed in the pericycle in species of *Cephalanthus*, *Chiococca*, *Coffea*, *Emmenopterys*, *Exostema*, *Ixora*, *Luculia*, *Mitriostigma*, *Pavetta*, *Pentas*, *Posoqueria*, *Randia*, *Rondeletia*, *Sarcocephalus*, *Vangueria*. Stone cells also seen in the pericycle in *Chiococca*, *Gardenia*, *Randia*, *Rondeletia*. Secondary **phloem** only rarely including fibres, e.g. in species of *Cinchona*, *Coffea*, *Pavetta*, and *Sarcocephalus*, but rod or stone cells occurring in this position in species of *Antirrhoea*, *Exostema*, *Remijia*. **Xylem** always in the form of a continuous cylinder traversed by narrow rays; vessels mostly with simple perforations; scalariform plates occasional (see 'Wood').

Crystals of the same kinds as those described under 'Leaf'. Solitary crystals seen at Kew in the unlignified tissues of the stem in species of *Coffea* (in the medullary rays only), *Gardenia* (sometimes large and very numerous), *Ixora*, *Pavetta* (forming a sheath around the pericyclic fibres in *P. caffra* Linn.), *Randia*; cluster crystals observed in the same species of *Gardenia*, *Ixora*, and *Randia* as well as in *Rondeletia* and *Vangueria*. Isodiametric or elongated sclerenchymatous cells, with crystals embedded in the walls, recorded in the primary cortex, phloem, and pith in members of the genera *Pavetta*, *Strumpfia*, *Webera*.

Secretory elements. Cells filled with brown contents (see also 'Leaf') recorded in the phloem of a few species of *Cascarilla*, *Fadogia*, *Vangueria*. Secretory cells with unidentified contents observed at Kew in the unlignified tissues of species of *Cephalanthus*, *Hoffmannia*, *Ixora*, *Luculia*, *Mitriostigma*, *Pentas*, *Psychotria*, *Randia*, *Rondeletia*, *Sarcocephalus*, *Vangueria*. Secretory sacs recorded in the cortex and pith of *Cinchona* and in the cortex of *Corynanthe*.

PEDUNCLE

Peduncle in *Canephora* described by Wernham (2415) as containing a flattened vascular cylinder surrounded by unequally developed, parenchymatous cortical tissue in the form of 'wings' supported internally by scattered bundles of fibres sometimes associated with a few vessels.

WOOD (Figs. 180 and 181)

Vessels typically small (less than 100 μ mean tangential diameter) and often very small (25–50 μ); up to medium-sized (100–200 μ) in some species of *Anthocephalus*, *Bathysa*, *Bikkia*, *Bothriospora*, *Capirona*, *Cephalanthus*, *Cosmibuena*, *Elaeagia*, *Emmenopterys*, *Ferdinandusa*, *Feretia*, *Genipa*, *Gonzalagunia*, *Gouldia*, *Henriquezia*, *Hymenodictyon*, *Jackia*, *Kotchubaea*, *Ladenbergia*, *Lasianthus*, *Macrocnemum*, *Mitragyna*, *Morinda*, *Nauclea*, *Neonauclea*, *Pinckneya*, *Psychotria*, *Sarcocephalus*, *Timonius*, and *Tribus*. Exclusively solitary, or nearly all solitary, in *Adina*, *Badusa*, *Catesbaea*, *Corynanthe*, *Coutarea*, *Crossopteryx*, *Dictyandra*, *Erythralis*, *Euclinia*, *Exostema*, *Feretia*, *Gardenia*, *Genipa*, *Gleasonia*, *Henriquezia*, *Isertia*, *Ixora*, *Jackia*, *Kadua*, *Kotchubaea*, *Ladenbergia* (1886), *Mitragyna* p.p., *Morelia*, *Neonauclea*, *Pausinystalia*, *Pavetta*, *Petunga*, *Plectronia*, *Pseudocinchona*, *Randia*, *Remijia*

(1886), *Retinophyllum* (1886), *Sarcocephalus*, *Scyphiphora*, *Sphinctanthus* (1886), *Stachyarrhena*, *Stevensia*, *Stylocarya* p.p., *Tribus*, *Tricalysia*, and *Vangueria*; with radial multiples of 4 or more cells in *Alibertia*, *Anisomeris*, *Calycophyllum*, *Cephaelis*, *Dolicholobium*, *Dorisia*, *Emmenopterys*, *Gillespiea*, *Gonzalagunia*, *Hamelia*, *Heinsia* p.p., *Hodgkinsonia*, *Machaonia*, *Mitragyna* p.p., *Morinda*, *Posoqueria*, *Psychotria* p.p., *Rondeletia*, *Rudgea*, *Rutidea*, *Timonius*, and *Uragoga* (Fig. 180 A); with a slight radial or oblique pattern in *Fernelia*, *Hamelia*, *Heinsia*, *Psychotria* p.p., and *Uragoga* and with a distinct oblique or tangential pattern in *Henriquezia* and *Platycarpum* (1886); commonly with a tendency for single vessels to be grouped together radially but separated by a single row of fibres (Fig. 181 G). Typically numerous; less than 5 per sq. mm. in *Anthocephalus*, *Bikkia*, *Hymenodictyon*, *Morinda*, and *Rutidea*; 5–20 per sq. mm. in *Heinsia* p.p., *Jackia*, *Kotchubaea*, *Mitragyna* p.p.,

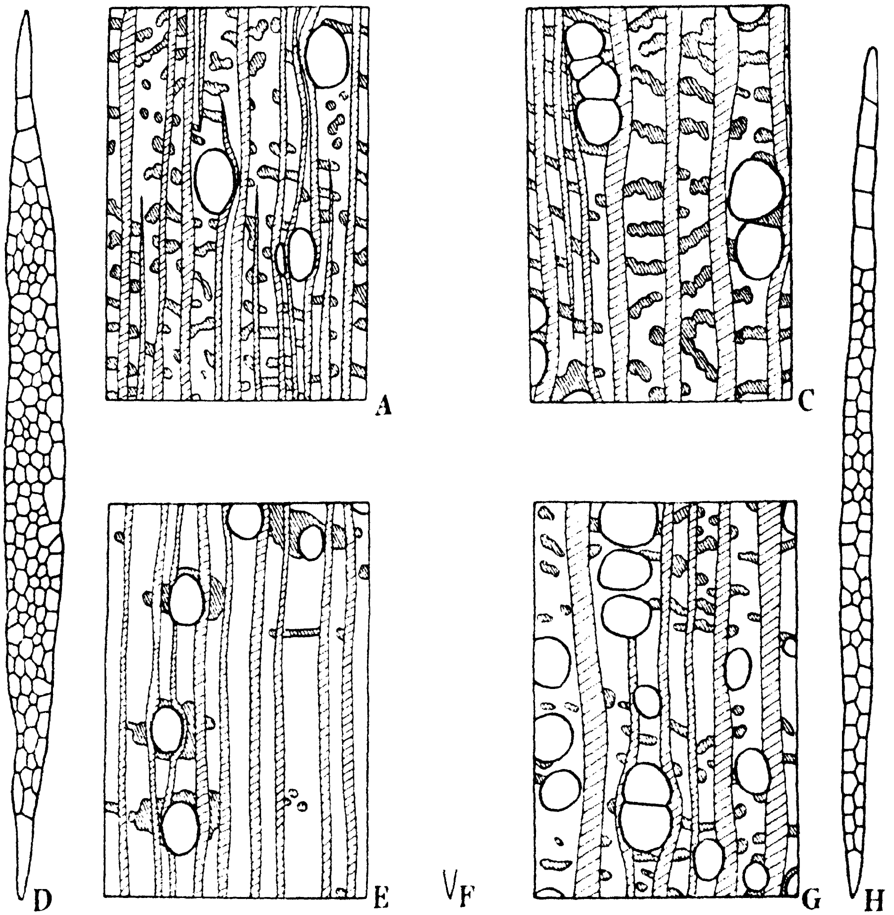


Fig. 181. *RUBIACEAE*

A, *Sarcocephalus esculentus* Afzel. B, *S. esculentus* Afzel. C, *Hymenodictyon excelsum* Wall. D, *Bobea mannii* Hillebr. E, *Henriquezia jenmani* Schum. F, *H. jenmani* Schum. G, *Mitragyna stipulosa* (DC.) O. Kuntze. H, *M. stipulosa* (DC.) O. Kuntze.

Nauclea p.p., *Pentagonia*, *Psychotria* p.p., *Sarcocephalus*, *Timonius*, *Tribus*, *Urophyllum*, and *Vangueria*; more than 20 vessels per sq. mm. in the other genera or species, very commonly 40–90 per sq. mm. and sometimes more than 100 per sq. mm., e.g. in species of *Coutarea*, *Luculia*, *Pavetta*, and *Stylocoryna*. Ring-porous in some species of *Cephalanthus* and *Pinckneya* and semi-ring-porous in some species of *Emmenopterys*, *Posoqueria*, and *Vangueria*; delicate spiral thickenings reported by Solereder to be common, e.g. in *Vangueria infausta* Burch., but observed only in *Emmenopterys* and then rare. Perforations in mature wood exclusively simple; Solereder, however, refers to the occurrence of both simple and scalariform plates (usually with few bars) in tissue near the primary wood in several genera; perforations between vessels and ray cells common (358), the plates sometimes irregularly reticulate. Intervascular pitting alternate, typically very small to minute, but rather larger in some species; vestured (78); pits to ray cells typically similar in size and shape, but with numerous, irregularly elongated and simple pits in *Psychotria eurycarpa* Standl. and *Rutidea coriacea* Baker. Solid contents often lacking or inconspicuous, but sometimes abundant; tyloses observed in *Gonzalagunia*, *Gouldia*, *Pinckneya*, *Rutidea*, *Tocoyena*, and *Uragoga*, and reported in *Chimarrhis* (2430), *Henriquezia*, *Kotchubaea* (1886), and *Sarcocephalus* (525). Mean member length 0·5–1·3 mm., mostly 0·5–0·8 mm.; about 1 mm. or longer in *Isertia*, *Mitragyna*, *Nauclea*, *Palicourea*, and *Psychotria*. **Parenchyma** typically apotracheal in those species with non-septate fibres, but vasicentric in *Cephalanthus*, *Ferdinandusa*, *Gouldia*, *Pittonotis*, and *Strumpfia*, and absent from *Emmenopterys*, *Sommera*, and *Straussia*; the apotracheal parenchyma usually as scattered cells tending to form short uniseriate lines (Figs. 180 J and 181 A), the latter sometimes moderately continuous and the lines more than 1 cell wide, e.g. in *Amaioua*, *Coutarea*, *Hymenodictyon* (Fig. 181 C), and *Rondeletia*; with broad bands, 4 or more cells wide in *Alibertia*, *Craterispermum* (Fig. 180 F), *Fernelia*, and *Stenostomum*; with discontinuous broad bands tending to form islands of parenchyma in some species, e.g. of *Durioia*, *Gaertnera* (Fig. 180 E), and *Hamelia*, and with widely separated bands that tend to be associated with the vessels in *Kotchubaea* and, to a less marked extent, in *Jackia*. The species with septate fibres typically without any parenchyma, e.g. in *Abramsia*, *Alseis*, *Bathysa*, *Calderonia*, *Calycodendron*, *Calycophyllum*, *Calycosia*, *Capirona*, *Cephaelis*, *Cosmiboena*, *Cosmicalyx*, *Dialypetalanthus*, *Dolicholobium*, *Elaeagia*, *Eumorphanthus*, *Gillespiea*, *Hedstromia*, *Hippotis*, *Holtonia*, *Macrocnemum*, *Mapouria*, *Notopleura*, *Palicourea*, *Pentagonia*, *Picardaea*, *Pogonocarpus*, *Psychotria*, *Uragoga*, and *Warscewiczia*; with scanty paratracheal parenchyma in *Bothriospora*, *Coussarea*, *Dorisia*, *Faramea*, *Machaonia*, and *Pseudoschima*, and with diffuse parenchyma in *Fernelia*. More abundant and aliform to confluent in *Henriquezia* and *Platycarpum* (1886). Usually without conspicuous contents; with solitary crystals in chambered cells in some species of *Coutarea* and *Pavetta*; and, according to Janssonius (1154), with large single crystals in *Hymenodictyon excelsum* Wall. and *Ixora* spp., and with occasional cells containing a crystalline mass in *Mussaenda frondosa* Linn.; with raphides in *Craterispermum*, *Faramea* (sometimes in the rays only, 959), *Morinda*, *Prismatomeris*, and *Psychotria* (sometimes in the rays only). Strands most commonly of 8 cells or more, sometimes of 4 very high cells. **Rays** often of

2 distinct sizes or appearing so owing to the large number of uniseriate rays or long uniseriate margins of the multiseriate rays; 2–3 cells wide in about 70 per cent. of the genera and seldom more than 6 cells wide, though occasionally up to 10 cells (1886), and, according to Solereder, up to 8 cells in *Coprosma lucida* Forst. J.; exclusively uniseriate or with only occasional biseriate parts in some species of *Bikkia*, *Henriquezia*, *Ixora*, *Kadua*, *Kotchubaea*, and *Scyphiphora*, and, according to Record and Hess (1886), in *Alibertia*, *Bertiera*, *Casasia*, *Cephalanthus*, *Coutarea*, *Erythralis*, *Exostema*, *Gleasonia*, *Henriquezia*, *Platycarpum*, *Retiniphyllum*, and *Tocoyena*; 4 or more cells wide in some species of *Bathysa*, *Bothriospora*, *Calycophyllum*, *Capirona*, *Cinchona*, *Coprosam*, *Coussarea*, *Cuviera*, *Dolicholobium*, *Elaeagia*, *Faramea*, *Ferdinandusa*, *Gardenia*, *Genipa*, *Guettarda*, *Hippotis*, *Hodgkinsonia*, *Holtonia*, *Ladenbergia*, *Machaonia*, *Macrocnemum*, *Mitragyna*, *Morinda*, *Nauclea*, *Oxyanthes*, *Palicourea*, *Pausinystalia*, *Pentagonia*, *Plectronia*, *Psychotria*, *Randia*, *Remijia*, *Rondeletia*, *Sickingia*, *Stylocoryna*, *Tarenna*, *Timonius*, *Uragoga*, *Urophyllum*, *Vangueria*, *Warscewiczia*, and *Wendlandia*, and, according to Record and Hess (1886), occasionally 6 cells wide in *Capirona*, *Chimarrhis*, *Hamelia*, and *Rudgea*. Commonly more than 1 mm. high and 2 or more rays often joined vertically; Francis (706) states that 'aggregate' rays occur in *Canthium latifolium* F. v. M. associated with the deep indentations characteristic of the mature stem; uniseriate rays usually very numerous and composed entirely of square to upright cells; 7–24 rays per mm., typically numerous, e.g. often 20 or more per mm. in some species of *Couterea*, *Euclinea*, *Luculia*, *Machaonia*, *Morelia*, *Oxyanthes*, *Rudgea*, *Scyphiphora*, *Tricalysia*, and *Uragoga*; fewer than 12 per mm. in about 30 per cent. of the genera; heterogeneous, often markedly so (Kribs's Types I and II A and III); typically with 4 to many marginal rows of high upright cells; the multiseriate parts of rays that have 10 or more marginal rows often limited to small groups of procumbent cells and sometimes with more than one such group per ray (Fig. 180 B and C), e.g. in some species of *Gaertnera*, *Gleasonia*, *Ixora*, *Nauclea*, *Psychotria*, and *Tribus*; the small multiseriate parts sometimes composed almost entirely of square cells, with very few truly procumbent cells; e.g. in *Coussarea*, *Euclinia*, *Faramea*, *Luculia*, *Palicourea*, *Pavetta*, *Pentagonia*, *Psychotria*, and *Uragoga*; species with rays 4 or more cells wide, usually less markedly heterogeneous, many of the rays with fewer than 4 marginal rows and with the greater part of the ray composed of procumbent cells, e.g. in some species of *Abramsia*, *Bikkia*, *Bothriospora*, *Cephaelis*, *Coprosma*, *Coutarea*, *Craterispermum*, *Crossopteryx*, *Cuviera*, *Dialypetalum*, *Dorisia*, *Duroia*, *Emmenopterys*, *Eumorphanthus*, *Exostema*, *Ferdinandusa*, *Fernelia*, *Genipa*, *Gouldia*, *Isertia*, *Jackia*, *Machaonia*, *Mitragyna*, *Morinda*, *Neonauclea*, *Notopleura*, *Palicourea*, *Pausinystalia*, *Pentagonia*, *Pinckneya*, *Psychotria*, *Randia*, *Retiniphyllum*, *Sickingia*, *Strumpfia*, *Stylocoryna*, and *Tarenna*; with sheath cells in *Bathysa*, *Cephaelis*, *Coprosma*, *Coussarea*, *Eumorphanthus*, *Faramea*, *Hippotis*, *Morinda*, *Oxyanthes*, *Pentagonia*, *Plectronia*, *Pogonocarpus*, *Prismatomeris*, *Psychotria*, *Randia*, *Tarenna*, *Trukia*, *Uragoga*, and *Wendlandia*. Link (1377) states that *Coffea arabica* can be distinguished from other species by the occurrence of cubical cells scattered through its rays. Solitary crystals present in a few species; raphides present in some species of *Calycodendron*, *Calycosia*, *Cosmibuena*, *Faramea* (1886), *Gillespiea*, *Psychotria*, and *Straussia*; upright cells

occasionally filled with crystal-sand, e.g. in some species of *Adina* (1154), *Anthocephalus* (1154), *Calycophyllum* (1522), and *Diplospora* (1154), or a crystalline mass, e.g. in *Mussaenda frondosa* (1154); the crystals or crystal-sand sometimes more abundant at the boundary or the growth ring (1154). **Fibres** either non-septate, with pits with small to very distinct borders, or septate, with simple to slightly bordered pits; septate in *Abramsia*, *Alseis*, *Bathysa*, *Bothriospora*, *Calderonia*, *Calycodendron*, *Calycophyllum*, *Calycosia*, *Capirona*, *Cephaelis*, *Chasalia* (2158), *Cosmibuena*, *Cosmocalyx*, *Damnacanthus* (2158), *Dolicholobium*, *Dorisia*, *Elaeagia*, *Eumorphanthus*, *Faramea*, *Fernelia*, *Gillespiea*, *Gonzalagunia*, *Guettarda*, *Hamelia* (2158), *Hamiltonia* (2158), *Hedstromia*, *Hippotis*, *Holtonia*, *Hypobathrium*, *Leptodermis* (2158), *Machaonia*, *Macrocnemum*, *Mapouria*, *Notopleura*, *Paederia* (2158), *Palicourea*, *Pentagonia*, *Picardaea*, *Pogonopus*, *Psychotria*, *Rudgea* (according to Solereder, 2158, but not in material examined), *Sickingia*, *Uragoga*, and *Warscewiczia*; septate but with moderately distinctly bordered pits in *Fernelia*, *Gonzalagunia*, and *Notapleura* and, according to Panshin (1649), in *Scyphiphora*; non-septate but without very distinctly bordered pits in *Casasia*, *Emmenopterys*, *Gouldia*, *Guettarda*, *Hamelia*, *Luculia*, *Pelagodendron*, *Posoqueria*, *Pinckneya*, *Rondeletia*, *Timonius*, *Tocoyena*, and *Tricalysia*. Walls moderately thin to very thick, tending to be thinner in the septate fibres. Mean length 0·6–2·2 mm., mostly 1·0–1·5 mm.; about 2 mm. or more in species of *Mitragyna*, *Psychotria*, *Sarcocephalus*, and *Timonius*. **Intercellular canals** of the radial schizogenous type reported by Janssonius (1154) in one specimen of *Hymenodictyon excelsum* Wall.

ROOT

Cork said by Holm (1056) to arise in the peripheral layer of the cortex in *Cephalanthus occidentalis* Linn. Larger roots of *Coprosma petriei* Cheesem. tough, woody, and provided with large vessels according to Foweraker (703).

Lemesle (1356) has recently described what is claimed to be an unusual type of element in the wood of the root (and sometimes of the stem) in species of *Psychotria* and *Uragoga*. These elements, termed 'tracheides ouvertes' or 'fibres aréolées conductrices', are similar to ordinary tracheids but differ in having simple perforations formed after several adjacent pits have coalesced.

The tuberous swollen roots of *Myrmecodia* are permeated with a network of chambers and passages inhabited by ants. These roots are diarch when young. Cambium is absent, but a network of secondary bundles arises in the primary parenchyma and also in phelloderm tissue which is formed during the development of the root. The cavities are formed by the activity of phellogen layers which arise in the parenchyma. These layers produce cork towards the inside and phelloderm externally. The cells enclosed by the layers of cork subsequently die, and so the cavities are formed. For further particulars see Treub (2278).

ANOMALOUS STRUCTURE

(A) Xylem masses with longitudinal furrows recorded in species of *Lygodisodea*, *Manettia*, *Sabicea* (sometimes splitting up into separate strands in this genus). (B) Secondary strands of xylem and phloem said to arise in the cortex of both stem and root in '*Chiococca racemosa*'. Anomalous thickening of the 'concentric' type (*c.l. circumvallatum*) occurs in *Basanacantha asperifolia* Sandw. and *Rhabdodendron*. The outstanding characters of the woods of *Basanacantha* and *Rhabdodendron* are discussed below.

ECOLOGICAL ANATOMY

Keller (1230) and Keller and Leisle (1232) have shown that '*Asperula glauca*' and *Galium verum* Linn., both from Steppe regions, have higher stomatal frequencies and transpiration rates than the woodland species *Asperula odorata* Lam. and *Galium cruciatum* Scop. The Steppe species possess acicular leaves with inrolled margins and a relatively thick mesophyll, including strongly developed palisade tissue and protected externally by a thick cuticle. Some details concerning the ecological anatomy of *Galium saxatile* Linn. have been recorded by Priestley and Hinchliff (1751). The xerophytic structure of '*Gaertnera deltoidea* Torr.' has been described by Lovejoy (1396), and the slight differences in the leaf structure in swamp and dune forms of *Cephalanthus occidentalis* Linn. by Starr (2188). The anatomy of the spreading, mat-like *Coprosma petriei* Cheesem. from New Zealand has been fully described by Foweraker (703) and an account of maritime and inland forms of *Spermacoce hispida* Linn. published by Mullan (1571).

TAXONOMIC NOTES

Gaertnera and *Hymenocnemis* have sometimes been regarded as members of the Loganiaceae. The anatomical structure, according to Solereder, favours their retention in the Rubiaceae.

Both Record (1842) and Heimsch (938) considered that, on the basis of its wood anatomy, *Rhabdodendron* is out of place in the Rubiaceae and, following Record (1842), the wood of *Rhabdodendron* has been described with those of the Phytolaccaceae (p. 1089).

Basanacantha differs from all the other genera of the Rubiaceae, except *Henriquezia* and *Platycarpum*, in having abundant confluent parenchyma and is further distinguished by the very unusual character of its parenchyma strands, which are divided up into 4 cells by septa and not by the usual cross-walls.

The wood of *Basanacantha*, though quite exceptional in some respects, possesses the rather unusual combination of distinctly bordered fibre pits and minute, alternate intervascular pitting that is one of the characteristic features of the woods of the Rubiaceae.

ECONOMIC USES

The most familiar economic product derived from this family is coffee, which consists of the roasted and ground seeds of various species of *Coffea*, particularly *C. arabica* Linn. The developmental anatomy of coffee leaves has recently been described by Varossieau (2323). Various members of the family yield dyes, notably *Rubia tinctorum* Linn. from S. Europe and *Morinda tinctoria* Roxb. and other species of *Morinda* from India. These products are now of restricted importance owing to the introduction of synthetic dyes. The structure and microchemical reactions of the root wood of *Morinda citrifolia* Linn. have been described by Tunman (2291).

The most important genus from the medicinal point of view is *Cinchona*, from the bark of the following species of which quinine is chiefly derived:

C. calisaya Wedd., *C. ledgeriana* Moens., *C. officinalis* Linn., *C. succirubra* Pav. Bark of hybrid origin is also important. The curved pieces of bark usually exhibit transverse fissures on the outer surface, but the appearance of these varies in different species. Longitudinal furrows on the outer surface are also common unless the outer bark has been exfoliated. The striated inner surface varies in colour from pale yellowish-brown to deep reddish-brown in different species and varieties. The microscopical characters include the narrow, irregular layer of compressed cork cells, frequently with brown contents; the cortex of somewhat tangentially compressed cells; the rather infrequent, solitary, secretory canals or sacs in the cortex; the broad zone of secondary phloem, consisting mostly of reddish-brown parenchymatous cells, but including disorganized remnants of sieve tissue, and dissected by medullary rays 1–3 cells wide; in the phloem, the numerous, large, mostly solitary but occasionally grouped, spindle-shaped fibres, up to 90 μ in diameter, with thick, concentrically zoned and pitted walls, often yellow in freshly cut sections; the fairly frequent, simple or up to 4-compound starch grains, occasionally reaching 15 μ in diameter, but usually somewhat smaller, the scattered cells containing crystal-sand.

According to Rosenthaler (1954) the root bark of the commercially important Cinchonas differs only in minor respects from that of the stem, notably in the shorter sclerotic cells and in the absence of secretory canals or sacs. The same author has also described the structure of *Cinchona* barks marketed in Hamburg under the names 'Castrona' and 'Naradjada' (Rosenthaler 1953). A recent preliminary account of the histology of cinchona and related barks from Colombia has been published by Little (1380).

Other Brazilian barks with febrifugal properties resembling those of *Cinchona* have been described by Brocardet (276) as follows:

(i) *Exostema cuspidatum* St. Hil. (Quina do Matto)

Cork consisting of 7 or 8 layers of tangentially elongated, thin-walled cells. Phelloderm, cortex, and pericycle not clearly differentiated. Phloem constituting most of the thickness of the bark; outer part containing radial rows of 5–7 sub-circular fibres, individual elements being 800–900 μ long. Ground tissue between the fibres composed of approximately hexagonal cells. Medullary rays 4 cells wide. Tannin and crystal-sand present in special cells.

(ii) *Cascarilla hexandra* Wedd. (Quina de Rio or Q. du Brésil)

Portions of the bark derived from the phloem include abundant fibres either solitary or in groups of 2–3, the individual elements being 50–70 μ in diameter and 800–900 μ long, with a few pits in the concentrically zoned walls. Medullary rays 3 cells wide. Crystal-sand present in scattered cells.

Other so-called Quina barks are also derived from species of *Cascarilla*, *Exostema*, and *Remijia* as well as from species not included in the Rubiaceae. For further details see Brocardet (l.c.). Another account of the microscopy of *Cinchona* barks and adulterants has been published by Ballard (114).

Ipecacuanha is derived from the root of *Cephaelis ipecacuanha* (Brot.) A. Rich. Commercial samples of the roots of this species consist of vermiform pieces, usually about 6 mm. thick. The white to greyish bark contracts and forms annular portions surrounding but easily detachable from the narrow, strong, central cylinder of xylem. The microscopical features include the narrow brownish layer of thin-walled cork cells; the broad secondary phloem, mostly composed of amyliferous parenchyma, the starch grains being simple or compound, the former up to about 15 μ in diameter; the solitary sacs of raphides embedded in the secondary phloem; the bright yellow xylem composed of radial rows of narrow vessels, mostly about 15–20 μ in radial diameter, and embedded in a ground tissue of prosenchymatous elements with bordered pits and amyliferous cells, all of these elements being difficult to distinguish in transverse sections owing to their approximately equal diameter. Lupton (1402) has described a microscopical method whereby small percentages of stem can be quantitatively estimated in samples of finely powdered ipecacuanha root. This is done by determining the proportion of the characteristic sclerotic cells, which are confined to the stem, in the sample to be examined. One milligram of ipecacuanha stem contains 33 of these sclerotic cells. A substitute for ipecacuanha, derived from *Manettia ignita* Schum., has been described by Maheu and Chartier (1418). Lemesle (1356) has recently described an unusual type of tracheid in the root wood of *Psychotria* and *Uragoga* (see 'Root', p. 771).

Yohimbe bark, derived from *Pausinystalia yohimba* Pierre et Beille, was at one time used in medicine as a source of yohimbine. The bark of several related species has been substituted for the genuine article. According to Small and Adams (2134), who have recorded many interesting chemical and microscopical particulars about these barks, the genuine material has a dark or greyish-brown outer surface with transverse cracks and longitudinal ridges forming a pattern of square patches. Inner surface reddish, finely striated and longitudinally ridged. Microscopical features include a thin layer of cork and narrow cortex both dark reddish-brown to yellowish-grey; medullary rays 1–3 cells wide with broadened distal ends; small scattered strands of pericyclic fibres; radial rows of spindle-shaped phloem fibres usually 1 cell wide, the individual fibres in a row frequently being separated from one another by single cells of phloem parenchyma. It is difficult to distinguish the genuine bark from that of related species. A German account of the structure and uses of Yohimbe bark has also been published by Brandt (260).

According to Holm (1056) the root and stem bark of *Cephalanthus occidentalis* Linn. has been used in medicine. The leaves of *Rudgea myrsinifolia* Benth. and *R. major* Muell. Arg., sometimes substituted for Maté Tea (*Ilex paraguarensis* St. Hil., see 'Aquifoliaceae' on p. 385), have been described and figured by Lendner (1357).

TIMBERS

The timbers of this family are not of first-rate commercial importance, though some of them are moderately well known to the timber trade or important locally. A species of *Gardenia* from Siam is sometimes used as a substitute for Boxwood, and Opepe or Bilinga, *Sarcocephalus diderrichii* De Wild., is a useful yellow timber that has a wide number of local uses and is sometimes exported. The tree is probably one of the most important species used for forestry plantations in West Africa. Abura or Bahia, *Mitragyna stipulosa* O. Ktze. and *M. ciliata* Aubrév. et Pellegr., are other West African timbers that are moderately well known. Haldu, *Adina cordifolia* Hook. f., is an important Indian timber, used for a great variety of purposes; Pearson and

Brown (1679) state that it is one of the best turnery woods in India and that selected pieces are attractively figured. These authors also list among the commercial timbers of India one or more species of the following genera: *Anthocephalus*, *Canthium*, *Gardenia*, *Hymenodyctyon*, *Morinda*, *Nauclea*, *Randia*, and *Stephegyne*. In South America *Calycophyllum* is the source of some important timbers, particularly the Pau Mulatto, *C. spruceanum* Benth., of the Amazon and the Palo Blanco, *C. multiflorum* Gris., of Argentina; Lemonwood or Degame, *C. candidissimum* (Vahl) DC., is a substitute for Lancewood and, according to Record and Hess (1886), is used for making bows in the U.S.A. Jagua or Genipa, *Genipa americana* L., is a timber with ash-like properties, which is widely used for purposes requiring strength and resilience rather than durability.

GENERA DESCRIBED

(i) GENERAL ANATOMY

Adenosacme, Adina, Alibertia, Alseis, Amaioua, Amaralia, Anthocephalus, Anthospermum, Antirrhoea, Argostemma, Asperula,* Aulacocalyx, Basanacantha, Bathysa, Bertiera, Bikkia, Bobea, Borreria, Bothriospora, Bouvardia, Burchellia, Callipeltis, Calycophyllum, Canephora, Canthium, Carpacoce, Cascarilla, Catesbaea, Cephaelis,* Cephalanthus,* Chasalia, Chimarrhis, Chiococca,* Chione, Chomelia, Cinchona,* Coccocypselum, Coffea,* Condaminea, Coprosma, Coptosapelta, Corynanthe, Coussarea, Coutarea, Craterispermum, Crossopteryx, Crucianella, Cruckshankia, Crusea, Damnacanthus, Danais, Declieuxia, Dentella, Deppea, Diodia, Diplospora, Dirichletia, Dolicholobium, Duroia, Emmenopterys,* Emmeorhiza, Erithalis, Ernodea, Exostema,* Fadogia, Faramea, Ferdinandusa, Feretia, Fernelia, Gaertnera, Gaillonia, Galiniera, Galium,* Galopina, Gardenia,* Genipa, Gonzalea, Greenea, Guettarda, Hamelia, Hamiltonia, Hedyotis, Heinsia, Hemidiodia, Henriquezia, Heterophyllaea, Hillia, Hindsia, Hippotis, Hoffmannia,* Holocarpa, Houstonia, Hydnophytum, Hymenodictyon, Hymenopogon, Hyptianthera, Isertia, Ixora,* Jackia, Kelloggia, Knoxia, Ladenbergia, Lasianthus, Laugeria, Lecananthus, Leptodermis, Leucodon, Limnosipanea, Luculia,* Lygodisodea, Machaonia, Macrocnemum, Malanea, Manettia,* Mapouria, Mericarpaea, Mitchella, Mitracarpum, Mitriostigma,* Molopanthera, Morinda, Mussaenda, Mussaendopsis, Myonima, Myrioneuron, Myrmecodia, Nauclea, Nematostylis, Nenax, Nertera, Octodon, Oldenlandia, Ophiorrhiza, Oreopolus, Otiophora, Otomeria, Paederia, Pagamea, Palicourea, Pauridiantha, Pavetta,* Pentagonia, Pentanisia, Pentas,* Pentodon, Perama, Petunga, Phyllis, Pinckneya, Plectronia, Plocama, Pogonopus, Polysphaeria, Polyura, Portlandia, Posoqueria,* Psathura, Psychotria,* Psyllocarpus, Putoria, Pyrostria, Randia,* Relbunium, Remijia, Retiniphyllum, Rhabdostigma, Richardsonia, Rondeletia,* Rubia,* Rudgea, Rustia, Sabicea, Saprosma, Sarcocephalus,* Schradera, Scolosanthes, Scyphiphora, Serissa, Sherardia, Sickingia, Silvianthus, Sipanea, Sommera, Spermacoce, Sphinctanthus, Spiradiclis, Staelia, Stephegyne, Stilpnophyllum, Strumpfia, Tammsia, Timonius, Tocoyena, Tresanthera, Tricalysia, Triodon, Uncaria, Urophyllum, Vaillantia, Vangueria,* Villaria, Warscewiczia, Webera, Wendlandia, Zuccarinia.

---

* Represented in the Kew slide collection.

(ii) For Wood Structure

Abramsia, Adina, Alibertia, Alseis, Amaioua, Anisomeris, Anthocephalus, Antirrhoea, Aulacocalyx, Badusa, Balmea, Basanacantha, Bathysa, Bertiera, Bikkia, Bobea, Bothriospora, Burchellia, Calderonia, Calycodendron, Calycophyllum, Calycosia, Canthium, Capirona, Casasia, Catesbaea, Cephaelis, Cephalanthus, (Chasalia), Chimarrhis, Chione, Chomelia, Cinchona, Coffea, Coprosma, Corynanthe, Cosmibuena, Cosmocalyx, Coussarea, Coutarea, Cratarispermum, Crossopteryx, Cuviera, (Damnacanthus), Dialypetalanthus, Dictyandra, Diplospora, Dolicholobium, Dorisia, Duroia, Elaeagia, Emmenopterys, Erithralis, Euclinia, Eumorphanthus, Exostema, Faramea, Ferdinandusa, Feretia, Fernelia, Gaertnera, Galiniera, Gardenia, Genipa, Gillespiea, Gleasonia, Gonzalagunia, Gouldia, Guettarda, Hamelia, Hedstromia, Heinsia, Henriquezia, Hippotis, Hodgkinsonia, Holtonia, Hymenodictyon, Hypobathrum, Isertia, Ixora, Jackia, Kadua, Kotchubaea, Lachnastoma, Ladenbergia, Lasianthus, Leptactinia, (Leptodermis), Luculia, Machaonia, Macrocnemum, Mapouria, Mitragyna, Morelia, Morierina, Morinda, Mussaenda, Mussaendopsis, Nauclea, Neonauclea, Notopleura, Oregandra, Oxyanthus, (Paederia), Palicourea, Pausinystalia, Pavetta, Pelagodendron, Pentagonia, Petunga, Picardaea, Pinckneya, (Platycarpum), Plectronia, Pogonopus, Posoqueria, Prismatomeris, Pseudocinchona, Psychotria, Randia, Remijia, Retiniphyllum, Rhytigynia, Rondeletia, Rudgea, Rutidia, Rytigynia, Sarcocephalus, Scyphiphora, Sickingia, Sommera, Sphinctanthus, Stachyarrhena, Stenostomum, Stevensia, Straussia, Strumpfia, Stylocoryna, Sukunia, Tarenna, Timonius, Tocoyena, Tricalysia, Trukia, Uncaria, Uragoga, Urophyllum, Vangueria, Vangueriopsis, Warscewiczia, Webera, Wendlandia, Zuccarinia.

Literature

(i) *On General Anatomy*

Ballard **114**, Boodle **236**, Brandt **260**, Brocardet **276**, Burgerstein **313**, Dop **597**, Fischer **686**, Foweraker **703**, Francis **708**, Holm **1056**, Jovet-Ast **1201**, Keller **1230**, Keller and Leisle **1232**, Lakon **1313**, Lemesle **1356**, Lendner **1357**, Little **1380**, Lovejoy **1396**, Lupton **1402**, Maheu and Chartier **1418**, Mariani **1440**, Melville **2529**, Mullan **1571**, Nicolas **1592**, Priestley and Hinchliff **1751**, Rosenthaler **1953**, **1954**, Sabnis **1977**, Shirley and Lambert **2092**, Small and Adams **2134**, Solereder **2162**, Starr **2188**, Tolle **2268**, Treub **2278**, Tunman **2291**, Varossieau **2323**, Wernham **2415**.

(ii) *On Wood Structure*

Bailey **78**, Beekman **167**, den Berger **179**, B.H. For. Dept. **274**, Besson **186**, Brown, F. B. H. **282**, Burgerstein **310**, **312**, Chalk *et al.* **364**, Chalk and Chattaway **358**, Cooper and Record **461**, Dadswell **525**, Descole and O'Donell **576**, Francis **706**, Frison **721**, Giordano **786**, **787**, Heimsch **938**, Hess **959**, Howard **1088**, Janssonius **1154**, Jones **1191**, Kanehira **1206**, Kribs **1283**, Lecomte **1334**, Link **1377**, Martin-Levigne **1450**, Méniaud **1491**, Meyer, F. J. **1505**, Milanez **1522**, Panshin **1649**, Pearson and Brown **1679**, Pfeiffer, H. **1712**, Pfeiffer, J. Ph. **1713**, Record **1783**, **1836**, **1838**, **1842**, **1843**, **1851**, **1884**, Record and Hess **1886**, Record and Mell **1894**, Riera **1937**, Scott **2075**, Stone **2202**, **2206**, Tang **2231**, Tunman **2291**, Williams **2430**, Yamabayashi **2478**.

165. VALERIANACEAE

(FIG. 182 on p. 778)

SUMMARY

A widely distributed herbaceous family, many members of which give off a characteristic smell when dried. The general anatomy is not very distinctive, but the **secondary xylem** of the more woody species exhibits the following features. **Vessels** extremely small, almost entirely in long radial multiples, with simple perforations and moderately large alternate intervascular pitting; members extremely short. **Parenchyma** absent. **Rays** 4–6 cells wide, moderately high, composed almost entirely of square or upright cells, occasionally absent. **Fibres.** Pits simple or with small borders. Extremely short. **Vascular tracheids** sometimes present.

LEAF

Dorsiventral in most species of *Centranthus*, *Fedia*, *Patrinia*, *Valeriana*, and *Valerianella*, but sometimes centric or almost homogeneous in a few species of *Valeriana*. **Hairs** include simple and glandular types. The former unicellular of varied length, or sometimes transversely septate; usually with thick walls. Glandular hairs consisting of unicellular or multicellular stalks and small multicellular heads. Multicellular bristles recorded in *Valeriana officinalis* Linn. **Stomata** present on both sides of the leaf or confined to the lower surface; sometimes paired in *Valerianella*; ranunculaceous. **Hydathodes** recorded in the leaf teeth of a few species of *Valeriana*. According to Stuart Thompson (2252) the presence of stiff white 'cilia' at the margins, and of white pits beneath the veins (both interpreted as hydathodes encrusted with calcium carbonate) serve to distinguish the radical leaves of *Valeriana dioica* Linn. from those of the unrelated but superficially similar *Parnassia palustris* Linn. (see 'Saxifragaceae', p. 553). Vascular bundles of the **veins** accompanied by collenchyma and not by sclerenchymatous elements. **Petiole.** Three vascular bundles usually entering the base, but forming an open arc of separate bundles towards the distal end (Fig. 182 A); individual bundles almost centric with central phloem in certain species of *Valeriana*. **Crystals** not recorded except in *Patrinia*. Sphaerocrystalline masses, probably consisting of inulin, sometimes seen in other genera after treatment with alcohol.

AXIS

STEM (Fig. 182 B)

Stems frequently hollow. **Cork** arising in the pericycle in *Centranthus ruber* DC.; not seen in other species. Outer part of the primary **cortex** collenchymatous. A well-defined, large-celled **endodermis** usually visible in young stems, but sometimes becoming less obvious when older. **Pericycle** devoid of sclerenchyma, but an incomplete ring of slightly elongated sclerotic cells with wide lumina noted in the inner part of the cortex of *Valeriana officinalis* Linn. **Vascular bundles** individually distinct in transverse sections of very young stems, but soon becoming connected by interfascicular prosenchymatous elements and a narrow zone of phloem to form a continuous cylinder. Vessels mostly with simple perforations; occasional scalariform plates in *Centranthus* (see 'Wood'). **Pith** becoming fistular.

WOOD

Vessels extremely small (mean tangential diameter less than 25 μ), in long radial multiples of 10 or more cells, which are seldom in contact with rays. Perforations simple and rather oblique; Solereder refers to scalariform perforation plates near the primary wood in a branch of *Centranthus ruber* DC. Intervascular pitting moderately large and alternate. Without contents. Mean member length about 0·15 mm. Associated with the vessel members are some similar cells that appear to have no perforations and should therefore be classified as **vascular tracheids. Parenchyma** absent. **Rays** multiseriate only, 4–6 cells wide, usually more than 1 mm. high; about 8 per mm.; composed almost entirely of irregularly arranged square or upright cells, with only an occasional row of procumbent cells, the outline of the ray very

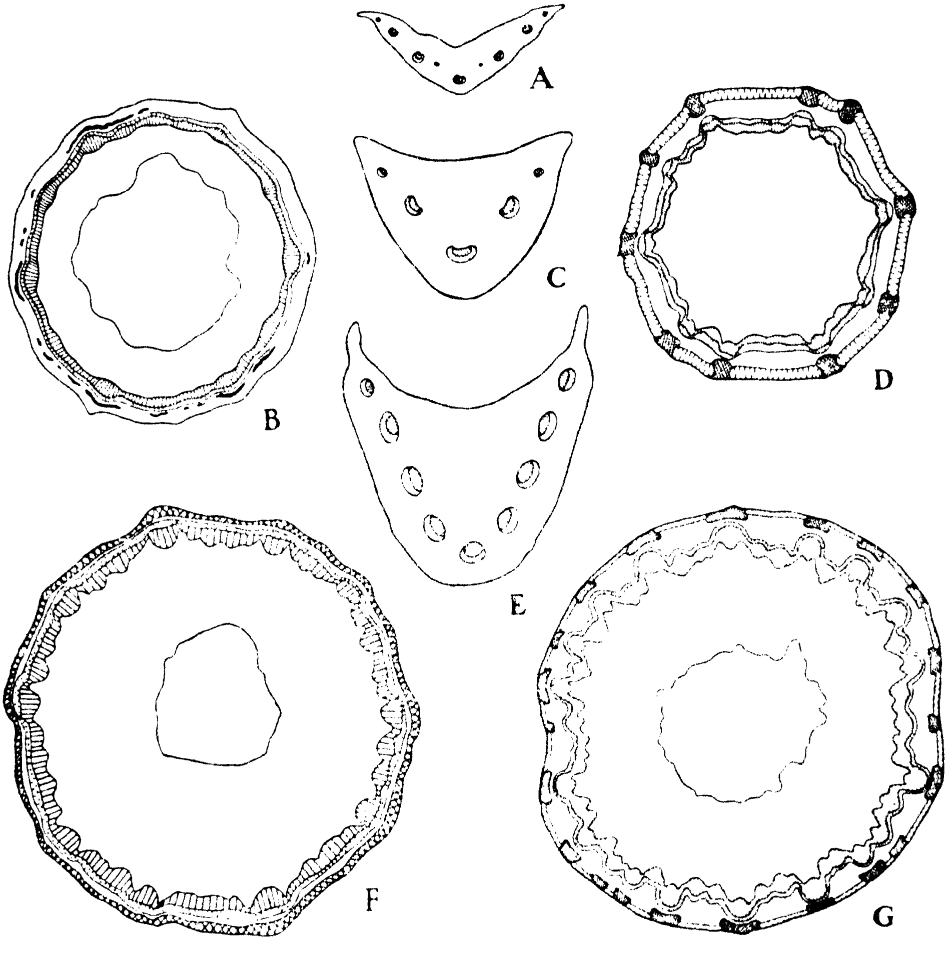


FIG. 182. *VALERIANACEAE*, A–B; *DIPSACACEAE*, C–G
A, *Valeriana officinalis* Linn. Petiole × 5. B, *V. officinalis* Linn. Stem × 6. C, *Scabiosa succisa* Linn. Petiole × 8. D, *Dipsacus fullonum* Linn. Young stem × 10. E, *Cephalaria alpina* Schrad. Petiole × 8. **F**, *Dipsacus fullonum* Linn. Old stem × 9. G, *Cephalaria alpina* Schrad. Stem × 7.

indefinite in tangential sections; sometimes with sheath cells. Solereder notes the absence of distinct ray parenchyma from a branch of *Centranthus*. **Fibres** with very thin to moderately thin walls; pits simple or with minute to small borders. Mean length about 0·27 mm.

ROOT

Cork arising superficially in some species but more deep-seated in others. Somewhat elongated **oil cells** with suberized walls occur in the outer part of the cortex and cork of *Centranthus*, *Fedia*, *Patrinia*, *Valeriana*, *Valerianella*.

TAXONOMIC NOTES

The anatomical structure, particularly of the stem, recalls that of the Dipsacaceae.

ECONOMIC USES

Extracts of valerian 'roots' (chiefly derived from varieties of *Valeriana officinalis* Linn.) are used in medicine on account of their carminative and antispasmodic properties. The strong, characteristic odour of the valerian plant exercises a very stimulating influence on cats. Commercial samples of the so-called 'root' consist of pieces of rhizome about 2–5 cm. long and 1–2 cm. thick, bearing numerous, crowded roots, about 2 mm. thick and up to 10 or more cm. long.

Transverse sections of the rhizome exhibit a circle of vascular bundles embedded in parenchymatous ground tissue, the vascular ring being greatly interrupted where branches to the crowded adventitious roots are given off; scattered, usually rather infrequent groups of yellow stone cells embedded in the parenchymatous ground tissue; abundant, simple and compound starch grains present, the individual components of which are mostly 8–12 μ, but sometimes up to about 20 μ in diameter. Transverse sections of the root exhibit the remnants of a piliferous layer; hypodermis of slightly suberized cells said to contain most of the ethereal oil; a broad amyliferous cortex constituting most of the thickness of the root; a well-defined endodermis of small cells; a thin-walled, small-celled pericycle not clearly differentiated from the phloem; xylem marked by a circle of vessels up to about 45 μ in radial diameter, surrounding a small central pith varying in size in different specimens. Mechanical elements absent from the root, and crystals from the root and rhizome.

Indian Valerian is derived from the rhizome and roots of *Valeriana wallichii* DC., and Javanese Valerian, according to Boelman (213), from *V. hardwickii* Wall. Spikenard (*Nardostachys jatamansi* DC.) yields an oil which has been much used in perfumery, especially in India.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Centranthus,* Fedia, Patrinia, Valeriana,* Valerianella.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

(Centranthus), Valeriana.

LITERATURE

(i) *On General Anatomy*
Boelman **213**, Fischer **686**, Thompson, H. S. **2252**.

(ii) *On Wood Structure*
Record **1843**, **1851**.

166. DIPSACACEAE

(FIG. 182 on p. 778)

SUMMARY

A small, old-world family of annual and perennial herbs which do not exhibit any very distinctive anatomical features.

LEAF

Dorsiventral or centric in different species of *Dipsacus* and *Scabiosa*; according to Schweitzer (2064) leaves dorsiventral at the base and isobilateral on the upper part of the stem in *Dipsacus laciniatus* Linn. and *D. sylvestris* Linn., but exclusively dorsiventral in *D. pilosus* Linn. Dorsiventral structure also recorded by Fischer (686) in *Knautia arvensis* (L.) Duby and *K. sylvatica* Duby. **Hairs.** (i) Unicellular, usually lignified, sometimes attached to multicellular emergences, in species of *Dipsacus*, *Knautia*, *Succisa*. (ii) Glandular, each having a short stalk and a head composed of a few cells in *Cephalaria*, *Dipsacus*, *Knautia*, *Scabiosa*, or a long uniseriate stalk and a multicellular head in *Knautia*. Superficial **spines** also occur in *Dipsacus* and glandular leaf-teeth in species of *Cephalaria* and *Knautia*. **Stomata** generally present on both sides of the leaf; but, according to Fischer (686), confined to the lower surface in *Dipsacus pilosus*; usually ranunculaceous, but, more rarely, cruciferous. Vascular bundles of the **veins** not accompanied by sclerenchyma; either embedded in the mesophyll or vertically transcurrent by thin-walled tissue. Collenchyma sometimes present in the midrib. **Petiole,** in transverse sections through the distal end, exhibiting a wide crescent of a few vascular strands in *Scabiosa succisa* Linn. (Fig. 182 C); similar but with about 9 vascular bundles in *Cephalaria alpina* Schrad. (Fig. 182 E). **Crystals,** when present, generally clustered. Cluster crystals found in the mesophyll of the species of *Dipsacus*, *Knautia*, and *Succisa* examined by Fischer (686). Crystalliferous idioblasts with thick walls recorded by Varga (2320) in the bracts of *Cephalaria speciosa* Boiss. et Kotsch.

AXIS

STEM (Fig. 182 D, F, and G)

Cork, according to Solereder, superficial in *Knautia* (pro parte); pericyclic in *Cephalaria*, *Dipsacus*, *Knautia* (pro parte). **Endodermis** with thickened walls recorded by Schweitzer (2064) in *Dipsacus*. **Pericycle** commonly devoid of mechanical elements, but long, thin-walled fibres noted at Kew in the pericycle of *Morina longifolia* Wall. **Xylem** and **phloem** soon forming a closed cylinder in *Cephalaria* (Fig. 182 G), *Dipsacus* (Fig. 182 D and F), *Morina*, *Scabiosa* (including *Succisa*) and probably throughout the family. Vascular bundles become interconnected at a very early stage by phloem and prosenchymatous elements, thus appearing in transverse sections as a continuous ring, with the outer periphery of the xylem frequently very sinuous in outline. Vessels in the primary xylem usually in radial rows; others, more irregularly distributed, become differentiated in the interfascicular xylem in relatively mature stems. Many of the vessels exhibit spiral thickening. Simple perforations noted at Kew in species of *Dipsacus* and *Triplostegia*; scalariform perforation plates also recorded by Solereder, but not seen in the material examined at Kew. Medullary rays mostly 1–2 cells wide. **Pith** usually broad, at first consisting of thin-walled tissue or collenchyma, but frequently becoming hollow when mature. Occasional **secretory cells** with unidentified contents noted in the pericycle of species of *Cephalaria* and *Dipsacus*. Cluster **crystals** observed in the cortex of *Morina longifolia* Wall. and in the cortex and pith of species of *Cephalaria*, *Dipsacus* (not in *D. fullonum* Linn.), *Morina*, *Scabiosa*, *Triplostegia*. **Laticiferous canals** not recorded.

RHIZOME

Pericyclic phellogen, and unlignified cells in the centre of the xylem recorded in *Dipsacus* by Schweitzer (2064).

TAXONOMIC NOTES

The stem structure of the Dipsacaceae is in many respects similar to that of the Valerianaceae.

GENERA DESCRIBED

Cephalaria,* Dipsacus,* Knautia, Morina,* Scabiosa* (including Succisa), Triplostegia.*

* Represented in the Kew slide collection.

LITERATURE

On General Anatomy

Fischer **686**, Schweitzer **2064**, Varga **2320**.

167. CALYCERACEAE

SUMMARY

The temperate and sub-tropical South American herbs belonging to the Calyceraceae have not received much attention from anatomists. Except where stated, the following description applies only to *Acicarpha* and *Boopis*, and particularly to *A. spathulata* R. Br. and *B. spathulata* Phil. It is noteworthy that the family differs from the Compositae in the lack of **external glands** and **secretory cavities,** whilst **phloem strands** are absent from the cortex.

LEAF

Stomata present on both surfaces; ranunculaceous.

AXIS

STEM

Acicarpha provided with a circle of **vascular bundles,** separated from one another by broad rays. Vascular bundles of several species of *Boopis* embedded in a ring of mechanical tissue. **Phloem** strands of *Acicarpha* accompanied externally by sclerenchyma consisting of rod cells and fibres. **Xylem** including moderately wide circular vessels with simple perforations and provided with bordered pits where in contact with the ray parenchyma; wood fibres consisting of elements with wide lumina, rather thick walls and simple pits. Clustered **crystals** abundant in the cortex and pith of *Acicarpha.*

GENERA DESCRIBED

Acicarpha, Boopis.

LITERATURE

On General Anatomy
Colozza **454**.

168. COMPOSITAE

(FIG. 183 on p. 784; FIG. 184 on p. 788; FIG. 185 on p. 790; FIG. 186 on p. 792)

SUMMARY

(i) GENERAL

The very large, widely distributed family of Compositae consists mostly of herbs, but includes some woody and arboreal types. Plants exhibiting a very wide range of habit are frequently classified in a single genus, as for instance *Senecio*, which includes small annual herbs, stem and leaf succulents as well as arboreal species. As would be expected, the anatomical structure of the family shows considerable diversity in correlation with these habit differences, whilst ecological specializations also occur. No comprehensive anatomical survey of the whole family has ever been made, so that it is impossible to give a complete account of the subject. There are, however, numerous features such as **secretory canals, laticiferous canals,** different types of glandular and non-glandular **hairs, anomalous secondary thickening,** and the occurrence of **medullary** and **cortical bundles** that are of considerable taxonomic value. It is interesting in this connexion to note the constancy of features such as secretory canals throughout a genus of such diverse habit as *Senecio.* **Herbaceous stems** throughout the family usually exhibit, in transverse sections, a ring of collateral vascular bundles, each of which is accompanied in the pericyclic region by a large strand of fibres. This structure is very familiar in *Helianthus annuus* Linn. The **stomata** are generally ranunculaceous.

(ii) WOOD

Vessels typically small and often with radial multiples of 4 or more and irregular clusters, often with a distinct radial or tangential pattern, commonly semi-ring-porous and sometimes with spiral thickening, perforations typically simple and horizontal, but with a few irregularly scalariform or reticulate plates in some species, intervascular pitting alternate, minute to moderately large, pits to parenchyma usually similar; members moderately to very short. **Parenchyma** typically rather sparse and paratracheal, fusiform cells sometimes common, often storied. **Rays** typically 4–10 cells wide, with few or very low uniseriates; exclusively uniseriate in a few species; sometimes storied; multiseriate rays typically composed of irregularly mixed upright and procumbent cells. Without rays in one species. **Fibres** with small, simple pits, occasionally septate, of medium length to very short. **Vasicentric tracheids** and **intercellular canals** in the rays occasionally present.

Hairs (Fig. 183)

A. *Non-glandular.* (i) Uniseriate, consisting of uniform cells apart from modifications of the terminal and basal cell (Fig. 183 A). (ii) Base consisting of a unicellular to uniseriate pedestal with a long, whip-like terminal cell (Fig. 183 B). This very common type often forms the web-like covering of the leaves of many members of the family, e.g. in species of *Achillea*, *Adenostyles*, *Anacyclus*, *Antennaria*, *Anthemis*, *Arctium*, *Artemisia*, *Atractylis*, *Baccharis*, *Bothriocline*, *Brickellia*, *Carlina*, *Centaurea*, *Centauropsis*, *Cineraria*, *Cirsium*, *Culcitium*, *Cynara*, *Dicoma*, *Echinops*, *Elephantopus*, *Eupatorium*, *Gnaphalium*, *Helichrysum*, *Hieracium*, *Ifloga*, *Liatris*, *Lucilia*, *Petasites*, *Phagnalon*, *Pulicaria*, *Raoulia*, *Rolandra*, *Senecio* (for further particulars of hairs in this genus see Hayek's (926) article), *Serratula*, *Silybum*, *Soaresia*, *Telmatophila*, *Vernonia*. (iii) Two-armed, each having a uniseriate stalk with a unicellular head (Fig. 183 F) recorded by Solereder in *Albertinia*, *Anacyclus*, *Anthemis*, *Artemisia*, *Centauropsis*, *Chrysanthemum*, *Eremanthus*, *Lychnophora*, *Olearia*, *Oliganthes*, *Parthenium*, *Piptolepis*, *Pithecoseris*, *Santolina*, *Senecio*, *Tanacetum*, *Vanillosmopsis*, *Vernonia*. Hess (958) has made a special study of the 2-armed hairs ('Zwillingshaare') in the Compositae, where they occur chiefly and sometimes exclusively on the pericarp. They have been found in all sections of the family, but not in all genera and species. They are most frequent and varied in form in the Astereae, Helenieae, Inuleae, and Senecioneae, and also numerous in certain species belonging to the Arctotideae, Eupatorieae, Heliantheae, Mutisieae, and Vernonieae. (iv) Stellate, each having a uniseriate stalk and a branched terminal cell in *Baccharis*, *Blanchetia*, *Haplostephium*, *Hieracium*, *Lychnophora*, *Olearia* (Fig. 183 D), *Piptocarpha*, *Piptolepis*, *Santolina*, *Vernonia*. (v) Candelabra-hairs, resembling superimposed stellate hairs, in *Hieracium* and *Scorzonera*. (vi) Bladder-like hairs, e.g. in *Zollikoferia* (*Launea*) *nudicaulis* Boiss. (Fig. 183 E). (vii) Shaggy hairs of various types (Fig. 183 M) especially prevalent in the Cichoreae and in *Hofmeisteria*, *Piptocarpha*, *Vernonia*. (viii) Unicellular hairs not recorded in the family. (ix) Peltate scales on short multicellular stalks noted on the stem of *Olearia albida* Hook. f.

B. *Glandular hairs.* (i) Each having a uniseriate or multiseriate stalk of varying length and of a unicellular to multicellular head; the whole structure sometimes depressed below the leaf surface, and then occasionally giving rise to pellucid dots. Glandular hairs of these types very widely distributed throughout the family, their secretion sometimes sufficiently profuse to give the leaves a varnished appearance, e.g. in species of *Baccharis*, *Brachylaena*, *Eupatorium*, *Gochnatia*, *Haplopappus*, *Helianthus*, *Olearia*, *Symphyopappus*. The similar coating of varnish, in species of *Celmisia* and *Vernonia*, said to be secreted by sub-epidermal idioblasts. (ii) Laticiferous hairs occur in the Cichoreae, notably on the involucral and other bracts in *Lactuca*, *Mulgedium*, *Sonchus*.

For the mode of secretion by glandular hairs in the Compositae see Klug's (1247) article.

SECRETORY ELEMENTS

A. 'RESIN' CANALS

'Resin' canals common, but by no means universally present throughout the family; occurring in the stem and leaf but most frequently in the root; generally situated in the region of the endodermis. Tetley (2243) differentiates between endodermal canals which are external to but whose formation is largely bound up with that of the endodermis, and non-endodermal canals which arise, particularly in the root, during later stages of development. 'Resin' canals usually lined with epithelium, except sometimes in the root. The number and distribution of the canals, especially in the stem, is said by Solereder to be valuable for the identification of genera, provided that allowance be made for displacements caused by secondary growth.

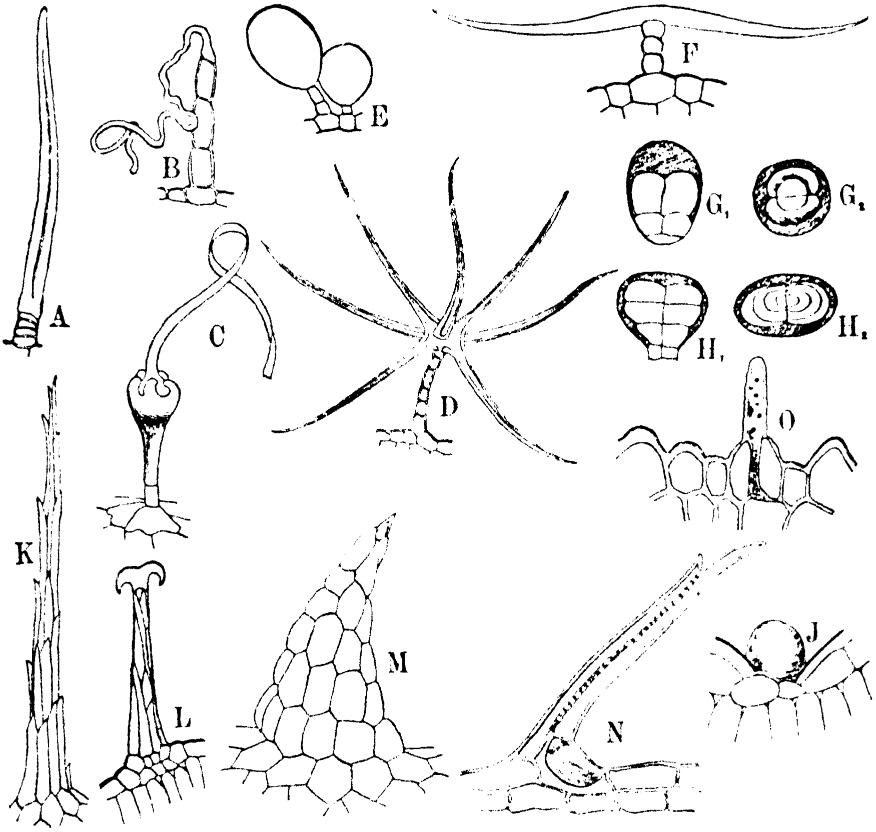


FIG. 183. *COMPOSITAE*

Hairy covering of the Compositae: A, *Catananche caerulea* L. B, *Cirsium vulgare* (Savi) Ten. (syn. *C. lanceolatum* (L.) Scop.). C, *Carlina vulgaris* L. D, *Olearia stellulata* DC. E, '*Zollikoferia nudicaulis* Boiss.' F, *Artemisia absinthium* L. G, '*Mikiania pubescens* Nutt.' H, *Chrysanthemum cinerariaefolium*, Vis. J, *Achillea fragrantissima* Schultz Bip. K, *Hypochoeris aetnensis*, Benth. et Hook. L, '*Picris coronopifolia* DC.' M, *Urospermum picroides* F. W. Schmidt. N, '*Spilanthes oleracea* L.' (floral region). O, *Lactuca scariola* L.—A, B, and K after Vesque; E, J, and L after Volkens; G, H, and N after Vogel; C, D, F, and M by Solereder.

(i) Canals in the cortex or in the region of the endodermis of the stem and, in some cases, extending through the petiole to the lamina of the leaf, recorded or observed in species of *Achillea*, *Achyropappus*, *Actinomeris*, *Adenostyles*, *Ambrosia* (Holm 1072), *Anacyclus*, *Anthemis*, *Arnica*, *Artemisia*, *Aster*, *Bellis*, *Cacalia*, *Carlina*, *Carthamnus*, *Cenia*, *Centaurea*, *Chrysothamnus*, *Cineraria*, *Cirsium*, *Cnicus*, *Cosmos*, *Cynara*, *Dahlia*, *Doronicum*, *Echinacea*, *Erigeron*, *Eriocephalus*, *Espeletia*, *Eupatorium*, *Flaveria*, *Galinsoga*, *Grindelia*, *Helianthus*, *Heliopsis*, *Hymenoxys*, *Inula*, *Leptosyne*, *Liatris*, *Lonas*, *Madia*, *Matricaria*, *Olearia*, *Parthenium*, *Petasites*, *Pulicaria*, *Pyrethrum*, *Santolina*, *Sanvitalia*, *Senecio*, *Serratula*, *Silphium*, *Silybum*, *Solidago*, *Tagetes*, *Tanacetum*, *Xanthium*, *Zinnia*. Faust (674) observed 2 concentric rings of resin canals with radial canals interconnecting the 2 longitudinal series in the upper part of the rootstock of *Balsamorhiza sagittata* Nutt., only the outer series of canals extending into the lowest part of the rootstock and subsidiary roots. Canals also occur in the cortex opposite the interfascicular regions and in the pith opposite the xylem. Root and stem canals in the same species said to arise as 2 separate systems and to remain distinct. (ii) Medullary canals present in species of *Actinomeris*, *Ageratum*, *Ambrosia* (Holm 1072), *Artemisia*, *Balsamorhiza* (Faust 674), *Baltimora*, *Bidens*, *Carduus*, *Carlina*, *Centaurea*, *Chrysanthemum*, *Cirsium*, *Coreopsis*, *Cosmos*, *Cynara*, *Dahlia*, *Doronicum*, *Echinacea*, *Gaillardia* (rhizome), *Galinsoga*, *Guizotia*, *Helianthus*, *Heliopsis*, *Iva*, *Lindheimera*, *Parthenium*, *Podachaenium*, *Polymnia*, *Serratula*, *Silphium*, *Solidago* (not in *S. odora* Ait. according to Holm, 1065), *Spilanthes*, *Tridax*, *Vernonia*, *Xanthium*, *Zaluzania*. (iii) Canals in the phloem recorded in the root of species of *Anacyclus*, *Carlina*, *Carthamnus*, *Centaurea*, *Dahlia* (fleshy roots), *Inula*; sometimes occurring in the same position in the branch as well in *Centaurea*, *Eupatorium*, *Galinsoga*, *Helianthus*. (iv) Canals in the branch and leaf also recorded in *Ainsliaea*, *Espeletia*, *Hyalis* (Benoist 172), *Lycoseris*, *Mutisia*, *Nassauvia*, *Polyachyrus*. (v) Canals in the root in species of *Gerbera*, *Stifftia* (see also under 'Root', p. 796). (vi) Canals said to be absent from the branch and leaf in species of *Actinolepis*, *Ammobium*, *Anaphalis*, *Antennaria*, *Arctotis*, *Baeria*, *Calendula*, *Calocephalus*, *Cardopatium*, *Cephalophora*, *Chaetanthera*, *Chaptalia*, *Chuquiraga*, *Cryptostemma*, *Dicoma*, *Dimorphotheca*, *Echinops*, *Elephantopus*, *Ethulia*, *Evax*, *Filago*, *Gerbera*, *Gnaphalium*, *Gochnatia*, *Helenium*, *Helichrysum*, *Helipterum*, *Humea*, *Inula* (pro parte), *Jasonia*, *Leontopodium*, *Leria*, *Leyssera*, *Lucilia*, *Micropus*, *Moquinia*, *Odontospermum*, *Olearia*, *Onoseris*, *Pallenis*, *Phagnalon*, *Podolepis*, *Podotheca*, *Proustia*, *Schlectendalia*, *Stifftia*, *Tarchonanthus*, *Tripteris*, *Triptilion*, *Ursinea*, *Venidium*, *Vernonia*, *Xeranthemum*.

B. SECRETORY CAVITIES

Secretory cavities, sometimes appearing as transparent dots of striae, occur in the leaf of species of *Athanasia*, *Baccharis* (Quentin 1765), *Liatris*, *Pectis*, *Porophyllum*, *Pulicaria* (Sabnis 1977), *Tagetes*, and also in the rays, phloem, and/or wood in the subterranean parts of species of *Anacyclus*, *Artemisia*, *Atractylis*, *Carlina*, and *Inula*. Secretory cavities also replace the canals in the axis of a few other genera, e.g. observed at Kew in the cortex of a species of *Amellus*. Secretory cavities with lignified walls recorded by Stadler (2180) in the outer part of the pith of '*Cnicus benedictus* Linn.'

C. LATEX CANALS AND SECRETORY CELLS

Laticiferous vessels especially characteristic of the Cichoreae, but occurring also in species of *Atractylis* (with rubber-like contents according to Casparis, 345), *Carlina*, *Gazania*, *Gundelia*; present in root, stem, and leaf. Laticiferous elements in the stem occur chiefly in the pericyclic region, but additional tubes sometimes arise in the cortex, secondary phloem, and in association with the medullary phloem bundles when the latter are present. Laticiferous elements of the leaf generally accompany the vascular bundles of the veins and occasionally penetrate somewhat into the mesophyll. The primary laticiferous system of the root arises at the internal margin of the primary phloem; but canals also occur in the secondary phloem of older roots (see also under 'Root'). Latex sometimes present in elongated secretory cells occurring in the same tissues as the canals. Laticiferous vessels occasionally replaced by cells with resinous or milky contents in species of *Arctium*, *Atractylis*, *Carduus*, *Carlina*, *Chardinia*, *Cirsium*, *Cousinia*, *Galactites*, *Gazania*, *Jurinea*, *Onopordon*, *Silybum*, *Staehelina*, *Vernonia*, *Warionia*. Secretory cells noted at Kew in the phloem of *Chondrilla juncea* Linn.

CRYSTALS

Rather rare and somewhat variable in form. Bundles of raphides present in the mesophyll of *Carlina vulgaris* Linn. and in the petiole of *Stifftia chrysantha* Mikan. Acicular crystals recorded in the root of *Atractylis* by Casparis (345), in *Pegolettia* by Sabnis (1977), and acicular and prismatic crystals in the stem pith of *Grindelia* by Holm (1048). Large, solitary crystals recorded in *Cacalia* and *Kleinia*. Clustered crystals, sometimes large, present in *Ambrosia* (Holm 1072), *Artemisia*, *Baccharis* (clusters of acicular prisms noted in this genus by Quentin 1765), *Bolanosa*, *Eremanthus*, *Eupatorium*, *Lychnophora*, *Pacourina*, *Vernonia*. Clusters of small, yellow, acicular crystals noted in a few species of *Cirsium* and *Dahlia*. Inulin particularly prevalent in the family, occurring especially but not exclusively in the root. Sphaerocrystals of gypsum also recorded.

LEAF

Generally dorsiventral, but sometimes exhibiting ecologically specialized forms such as: (i) Rolled leaves in *Olearia solandri* Hook. f. (ii) Scale-like leaves in *Helichrysum* spp., *Lepidophyllum quadrangulare* Benth. et Hook. f., and *Phaenocoma prolifera* D. Don. (iii) With well-developed sclerotic hypoderm beneath both upper and lower surfaces, the 2 zones being connected to one another by plates of sclerenchyma in the mesophyll of *Celmisia lyallii* Hook. f. For range of leaf structure in Madagascan species of *Senecio* see Humbert's (1107) paper, and for particulars of other ecological specializations under 'Ecological Anatomy', p. 797. **Epidermis** not uncommonly including groups of silicified cells. Rosettes of silicified cells sometimes surround the bases of the hairs, e.g. in *Helianthus*, *Heliopsis*, *Rudbeckia*, and, according to Werner (2414), in *Zexmenia*. A layer of aqueous **hypoderm** recorded immediately below the upper epidermis by Kienholz (1236) in *Wedelia biflora* DC. Alexandrov (12) refers to large, water-storage cells bordering on the intercellular spaces in *Helianthus annuus* Linn. **Stomata** variously distributed, mostly ranunculaceous to cruciferous. Stomata absent from submerged, but present on both surfaces of aerial, leaves of the aquatic *Megalodonta beckii* (Torrey) Greene according to Hoeck (983). Small groups of stomata on both surfaces of the leaf overlying areas of assimilatory tissue recorded by Holm (1048) in *Grindelia squarrosa* (Pursh.) Dunal. **Hydathodes** at the ends of the veins occur in *Senecio saxifragoides* Hook. f. and *S. lagopus* Raoul, according to Wall (2346). **Mesophyll** very variable; composed wholly of palisade cells in *Senecio magnificus* F. v. Muell. according to Betts (190); isobilateral, with loose palisade tissue towards both surfaces in *Wedelia biflora* according to Kienholz (1236). Vascular bundles of the **veins** frequently provided with a distinct sheath of parenchyma. The projecting nerves on the lower surface of the leaf of *Espeletia hartwegiana* Cuatr. consist mostly of collenchyma according to Benoist (172).

Petiole (Figs. 184 and 185), in transverse sections through the distal end of material examined at Kew, generally showing a simple arc of separate bundles, but varying from a flattened crescent of a few bundles, e.g. in species of *Achillea* (Fig. 184 F), *Baccharis* (Fig. 185 E), *Erigeron* (Fig. 184 D), and *Santolina* (Fig. 185 C), to a much deeper one consisting of numerous bundles, e.g. in species of *Arctium* (Fig. 184 C), *Cirsium* (Fig. 184 E), *Eupatorium* (Fig. 185 J), and *Sericocarpus* (Fig. 185 L). More complex types include a partly double arc with the adaxial series of bundles inversely orientated in *Helianthus tuberosus* Linn. (Fig. 184 A); an arc of separate bundles accompanied by medullary strands in *Silphium perfoliatum* Linn.; a circle of numerous bundles in *Dahlia* (Fig. 184 G and 185 G). Petiolar bundles with an arc of phloem around the inner edge of the xylem in *Cichorium intybus* Linn., *Galinsoga parviflora* Cav. and *Venidium decurrens* Less. Petiole provided with leaf-like wings in many genera, or, in others, with a peripheral zone of chlorenchyma. Petiole sometimes covered with a thick cuticle, e.g. in species of *Olearia* and other xerophytes. Ground tissue of the petiole including very numerous suberized cells in *Stifftia chrysantha* Mikan. No essential differences of structure between lobed and entire leaves of *Taraxacum officinale* Weber noted by Curtis (516).

AXIS

STEM (Fig. 185 B, D, F, H, I, K)

Sometimes ribbed, with sclerenchyma in the angles. Bounded externally by an **epidermis** of dead cells, with 2–4 layers of suberized or lignified cells immediately below the epidermis in *Olearia virgata* Hook. f. according to Betts (190). A persistent epidermis also noted at Kew in other genera. **Cork,** when present, generally superficial, e.g. in species of *Achillea*, *Artemisia*, *Aster tripolium* Linn., *Baccharis*, *Barnadesia*, *Cacalia*, *Chrysanthemum*, *Hieracium*, *Launea*, *Parthenium*, *Scorzonera*, *Tarchonanthus*. Pericyclic cork noted at Kew in *Aster novaeangliae* Linn. and *Stifftia chrysantha* Mikan.; first-formed cork sub-epidermal, a second layer subsequently arising in the pericycle in *Aplopappus lyallii* A. Gray. Bark peeling in narrow strips from old stems of *Artemisia tridentata* Nutt. and composed, according to Diettert (588), of layers of cork and sclerenchyma alternating with weak, thin-walled phloem cells. Flowering branches of the same species said to die owing to detachment of the bark.

Cortex. Outer part usually consisting of collenchyma, of chlorenchyma, or of alternating segments of collenchyma and chlorenchyma. Cortex in other species broad and composed of aqueous tissue, e.g. in *Aster tripolium* and *Venidium decurrens* Less. Outer cortex described by Betts (190) as lignified and suberized and sharply differentiated from the thin-walled inner cortex in *Cassinia vauvilliersii* Hook. f. var. *rubra* Buch. and *Helichrysum bellidioides* Willd. Sclerosed cells occur embedded in the cortical parenchyma of certain species of *Baccharis* according to Quentin (1765).

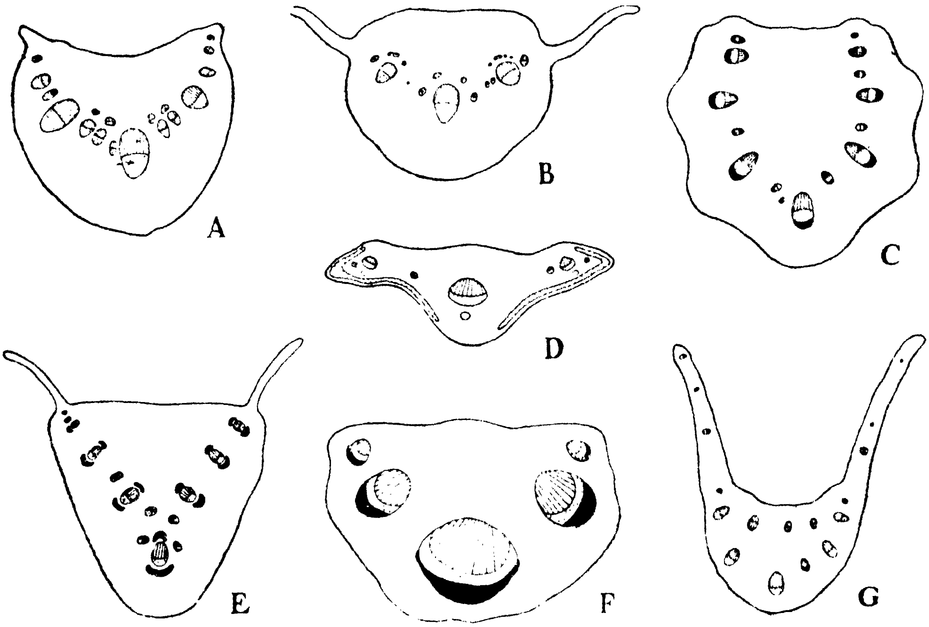


FIG. 184. *COMPOSITAE*

A, *Helianthus tuberosus* Linn. Petiole × 7. B, *Actinomeris squarrosa* Nutt. Petiole × 13. C, *Arctium vulgare* (Hill) A. H. Evans. Petiole × 5. D, *Erigeron canadensis* Linn. Petiole × 14. E, *Cirsium* sp. Petiole × 6. F, *Achillea grandiflora* Bieb. Petiole × 19. G, *Dahlia coronata* Hort. Petiole × 5.

Endodermis usually well defined, but various types occurring in the different genera and species. Endodermis sometimes appearing as a starch sheath; consisting of enlarged, uniformly thickened cells in a few species of *Aster*, *Lactuca*, and *Layia* (cells completely suberized) examined at Kew; well-marked casparian thickenings noted in species of *Cichorium*, *Cosmos*, *Erigeron*, *Felicia*, *Tagetes*, and *Xanthium*; with the radial and inner tangential walls strongly thickened (apart from the passage cells) in *Barnadesia rosea* Lindl. A suberized endodermis noted in ecologically specialized species of *Helichrysum* by Zemke (2505) and an endodermis of thickened cells in old stems of *Raoulia* by Foweraker (703). **Pericycle** nearly always including sclerenchyma, the latter being most frequently in the form of crescent-shaped strands at the outer boundary of the phloem groups of the vascular bundles, but almost or quite continuous in a few species, e.g. in *Baeria aristata*, *Eupatorium perfoliatum* Linn. (Holm 1031), *Inula squarrosa* Linn., and *Solidago odora* Ait. (Holm 1065). Crescent-shaped strands of pericyclic fibres united by the lignified distal ends of the medullary rays to form a continuous circle recorded by Obermeyer (1625) in certain species of *Artemisia*. **Phloem** commonly including sclerenchymatous elements. Lignified phloem recorded by Boodle (231) in *Helianthus annuus* Linn., a feature confirmed and more fully examined by Alexandrov (15). For lignified phloem in other genera see under 'Anomalous Secondary Thickening' on p. 795. Typical herbaceous stems usually provided with a single ring of collateral **vascular bundles** (Fig. 185 F, I, and K), but bundles closely placed or even forming a woody cylinder in the shrubby and arboreal members of the family (Fig. 185 D). The course of the vascular bundles in stems of *Helianthus annuus* has been described by Alexandrov and Alexandrova (18). Irregularly distributed and variously orientated vascular bundles recorded by Solereder in *Cynara cardunculus* Linn. and *C. scolymus* Linn. Hollow scape of *Taraxacum officinale* Weber described by Guir and Burress (844) as containing about 32 bundles. **Xylem** less dissected in the more woody and/or xerophytic members of the family. A band of xylem in *Helichrysum bellidioides*, infrequent rays 1–3 cells wide in *Olearia virgata* Hook. f. and an absence of rays in *Cassinia vauvilliersii* var. *rubra* mentioned by Betts (190). For the special stem structure of the arboreal Senecios and Espeletias see p. 791. Vessels usually with simple perforations; reticulate or scalariform plates occasional.

Cortical vascular bundles present in species of *Achillea*, *Ammobium*, *Anthemis*, *Arctium* (large bundles each accompanied by an arc of smaller ones), *Atractylis*, *Centaurea*, *Cirsium* (each cortical bundle accompanied by an arc of imperfect strands), *Crepis*, *Echinops*, *Erigeron*, *Felicia*, *Gundelia*, *Helenium*, *Jasonia*, *Leptosyne*, *Liatris* (each bundle accompanied by an arc of smaller ones), *Madia*, *Olearia*, *Senecio*, *Sericocarpus*, *Serratula*, *Tanacetum*, *Venidium*, *Vernonia*. Leaf trace bundles with internal (intraxylary) phloem recorded by Whitaker (2417) in *Solidago*.

Variously distributed **medullary bundles,** representing branches of the peripheral ring of strands, sometimes serve as an aid in the identification of species. The position and structure of the medullary bundles is uniform throughout the stem in some species, but their distribution varies at different levels in others. Medullary bundles usually collateral, rarely centric with central phloem; sometimes incomplete and consisting, for instance, of phloem only. Medullary bundles recorded or observed in species of *Centaurea*, *Crepis*, *Dahlia*, *Gundelia*, *Helenium*, *Hymenonema*, *Hyoseris*, *Lactuca*, *Leontodon*, *Mulgedium*, *Picridium*, *Picris*, *Pyrrhopappus*, *Rodigia*, *Rudbeckia*, *Saussurea*, *Scolymus*, *Scorzonera*, *Sonchus*, *Thrincia* (rhizome) (Nicolas 1590), *Tragopogon*, *Urospermum*. The medullary bundles of *Scorzonera* not always very obvious, being arranged in 2 or more distinct rings. The arrangement, size, and orientation of the bundles are said by Solereder to be of specific diagnostic value in this genus.

Worsdell (2471) regards the medullary bundles of the Compositae, like those of other families, as vestigial structures to be interpreted as relics of the scattered bundle system which is believed to have existed in ancestral forms. The medullary bundles of the Compositae vary in the extent to which they are complete at different levels in an individual plant. They are usually most complete towards the upper part of the axis, where each strand consists of xylem and phloem. Elsewhere they lose first their xylem and then their

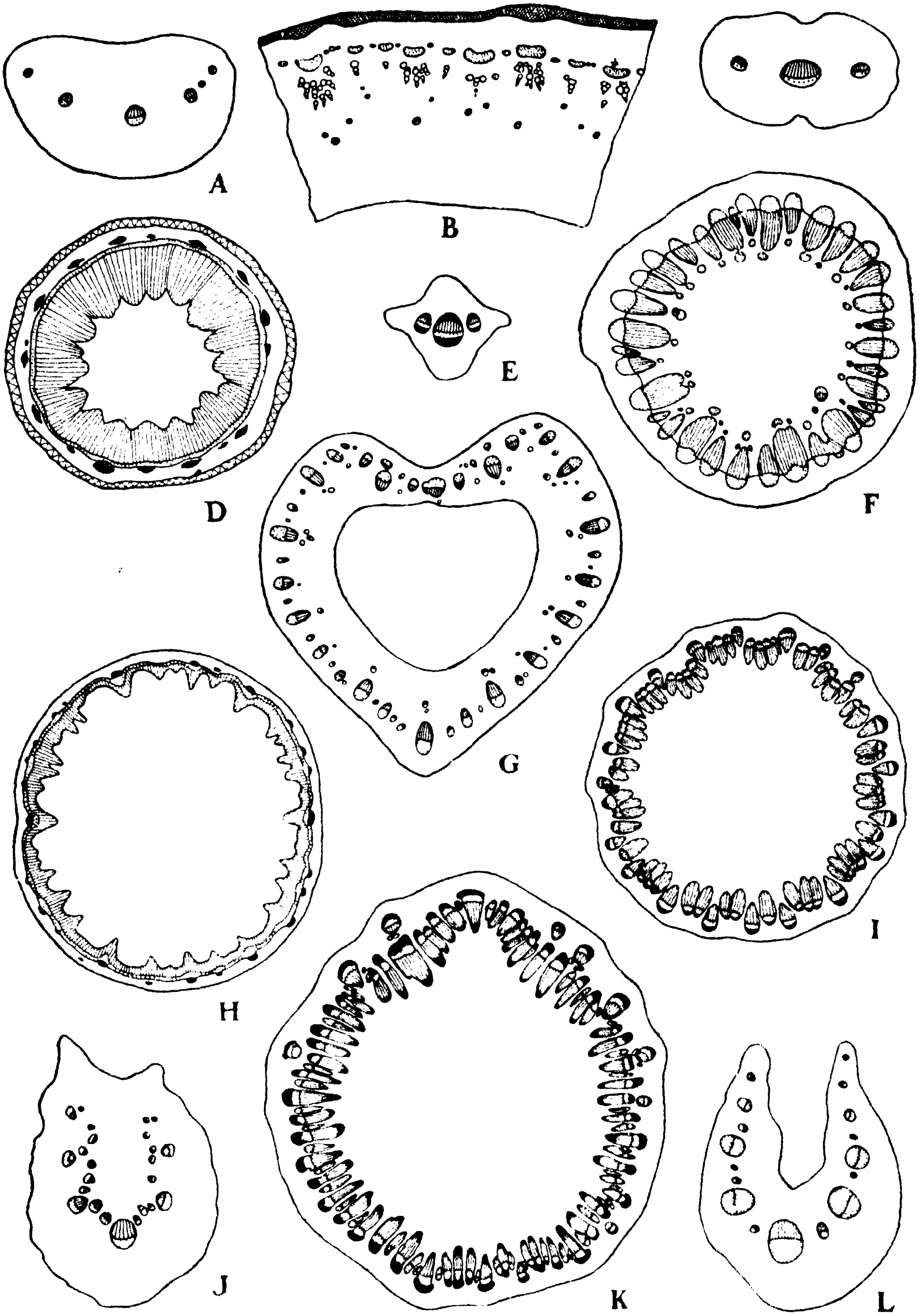


FIG. 185. *COMPOSITAE*

A, *Aster tripolium* Linn. Petiole × 14. B, *Dahlia maximiliana* Hort. Stem × 8. C, *Santolina chamaecyparissus* Linn. Petiole × 28. D, *Artemisia procera* Willd. Stem × 8. E, *Baccharis halimifolia* Linn. Petiole × 14. F, *Tragopogon porrifolius* Linn. Stem × 7. G, *Dahlia maximiliana* Hort. Petiole × 5. H, *Cosmos diversifolius* Otto. Stem × 8. I, *Vernonia altissima* Nutt. Stem × 8. J, *Eupatorium purpusii* Brandegee. Petiole × 15. K, *Arctium vulgare* (Hill) A. H. Evans. Stem × 5. L, *Sericocarpus conyzoides* Nees. Petiole × 19.

functional phloem, whilst some end blindly in parenchymatous tissue. Centric and inversely orientated medullary bundles also occur. Within a genus the stems of some species contain medullary bundles, whilst they are absent from others, e.g. in *Lactuca* and *Rudbeckia.* Even within a species there are some individuals with, and others without, medullary bundles, e.g. *Arctium lappa* Linn., *Crepis taraxacifolia* Thuil., and *Senecio clivorum* Maxim. Plants devoid of medullary bundles are regarded by Worsdell as more specialized than those in which they are present. Medullary bundles sometimes arise below the flowers, sometimes from the vascular ring of the lateral branches, and others from the vascular ring of the main stem. They frequently arise in the pith, and certain of them join the main vascular ring at a lower level, but others end blindly below. Occasionally a vascular strand leaves the vascular ring and almost immediately rejoins it at a lower level. Medullary bundles of the stem are not continuous with those of the leaf, but those of the stems and branches are directly connected, e.g. in *Helminthia* and *Scorzonera.*

Pith often consisting of thin- or thick-walled cells, but sometimes becoming hollow; septate in *Senecio praecox* DC.; always sclerified in *Baccharis* (Quentin 1765).

Developmental Anatomy. This has been described for *Helianthus* by Thoday (2250), Priestley and Scott (1753), and Esau (661); for *Bidens tripartita* Linn. by Graf (801); for *Parthenium argentatum* Gray by Artschwager (43). The histological response to wounding in stems of *Kleinia articulata* Haw. has been investigated by Woodhead (2463).

The Arboreal Senecios and Espeletias

The morphology of the arboreal Senecios, with their megaphytic habit, has been fully discussed by Cotton (482, &c.) who has pointed out that their anatomy recalls that of very large herbs rather than of reduced trees. This opinion concerning their structure is based on Hare's (890) careful investigation of the anatomy of the arboreal Senecios which grow on Kilimanjaro. Transverse sections of the stem of young seedlings show a ring of vascular bundles, whilst the general topography of the stem recalls that of the herbaceous species of *Senecio* such as *S. vulgaris* Linn. Additional vascular bundles are soon differentiated, however, so that the xylem gradually assumes, in transverse appearance, an almost continuous vascular cylinder. The xylem tends to be differentiated later than the phloem. There is a ring of secretory canals at the outer periphery of the vascular bundles and others in the cortex. In mature stems there is a broad cylinder of xylem surrounding the large pith, the latter persisting for some time and serving for the storage of water. The outside of the trunk is covered with the bases of crowded leaves. Numerous leaf traces enter the base of each leaf. There is no definite abscission layer, but the leaves break off along a line of weakness at a point near their bases, where there is an interruption in the strands of fibres which accompany the vascular bundles. A mycorrhizal fungus occurs in a band of dark-coloured cells in the outer part of the cortex. For further details see under 'Root', p. 796, and 'Ecological Anatomy', pp. 797–8.

The structure of the arboreal Senecios recalls that of the Espeletias, an American genus of which some species have a similar megaphytic habit. The taxonomy of *Espeletia* has been fully described and discussed from the phylogenetic standpoint by Smith and Koch (2142). Benoist (172) has described

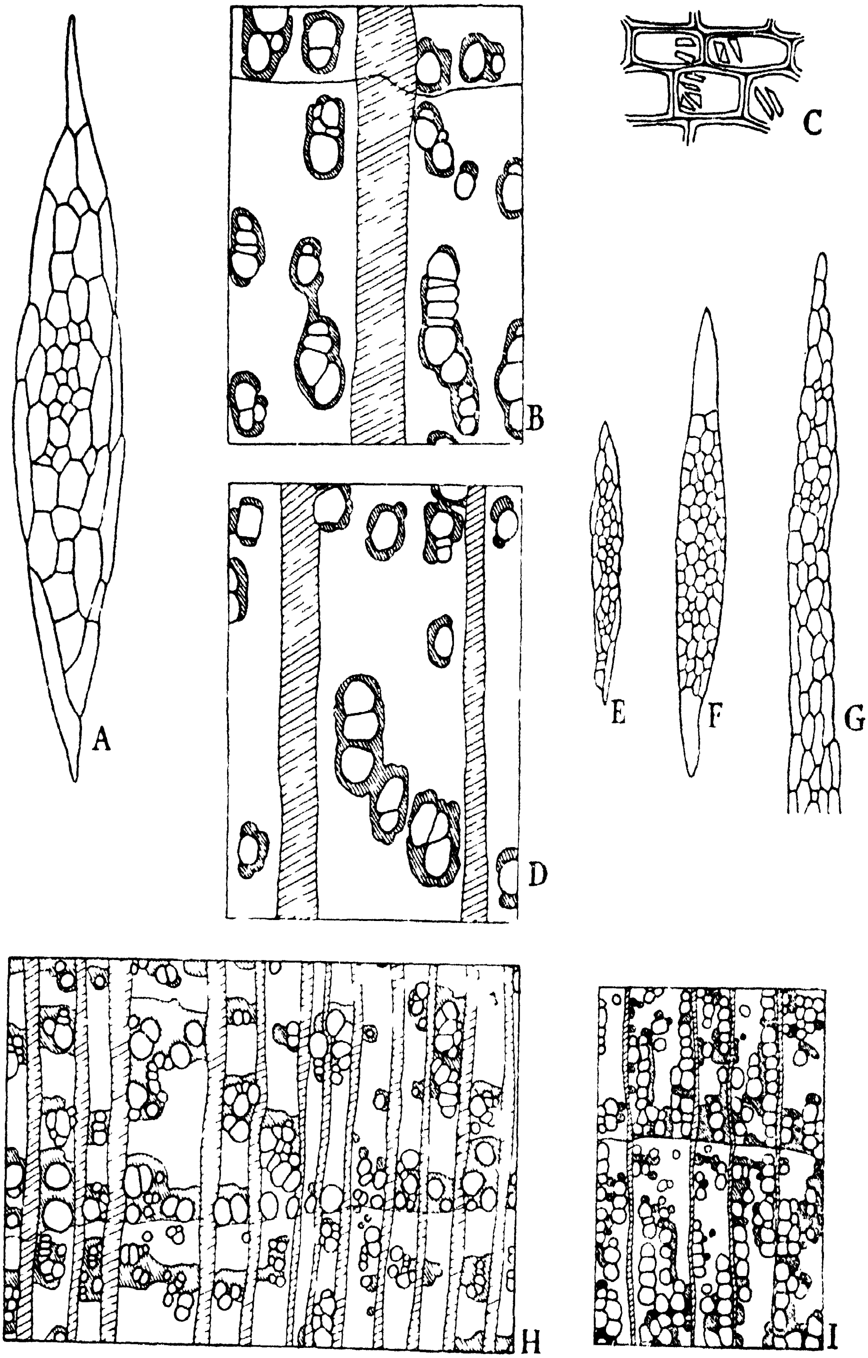


FIG. 186. *COMPOSITAE*

A, *Senecio adnivalis* Stapf. B, *Eupatorium hiemale* Lillo. C, *Proustia pungens* Poepp. Cells containing crystals. × 190. D, *Senecio erici-rosenii* R. E. et T. C. E. Fries. E, *Flourensia riparia* Griseb. F, *Faujasia* sp. G, *Artemisia arborescens* Linn. H, *Baccharis tucumanensis* Hook. et Arn. I, *Brachylaena hutchinsii* Hutchinson.

the anatomy of *Espeletia hartwegiana* Cuatr., old stems of which have a large pith surrounded by a ring of xylem, the cortex bearing the bases of fallen leaves. In the xylem, the circular or elliptical vessels, which are solitary or arranged in groups of 2, 3, or, more rarely, 4, have a maximum diameter of 50–100 μ and a density of 21 per sq. mm. Xylem parenchyma is scanty and paratracheal. The rays, 3–15 cells wide, are composed of radially elongated cells. The ground tissue of the wood consists of fibres with a maximum diameter of 25–50 μ and provided with small, vertically elongated pits. The phloem is in the form of a continuous ring. The inner part of the cortex consists of unlignified parenchyma, supported by large strands of sclerenchyma, numerous secretory canals being present further towards the outside. The peripheral part of the cortex is lignified. In young stems, secretory canals occur throughout the cortex and in the outer part of the pith, cortical, leaf trace bundles also being visible. The vessels are scarcely lignified and are arranged in slightly sinuous, long, radial series. In the inflorescence axis there is a circle of about 95 vascular bundles, each supported both externally and internally by sclerenchyma. Benoist's description includes some particulars concerning the leaf structure of *E. hartwegiana*.

WOOD (Fig. 186)

Vessels typically small (less than 100 μ mean tangential diameter), very small (less than 50 μ) in some species of *Artemisia*, *Baccharis*, *Brachylaena*, *Eupatorium*, *Flotovia*, *Gochnatia*, *Inula*, *Santolina*, *Stoebe*, and *Wedelia*; sometimes with groups of minute angular vessels, looking like tracheids, in *Inula* and *Santolina*, the groups often extending radially in *Inula*; with rather similar groups of minute, clustered vessels accompanying large (more than 200 μ) solitary ones in *Mikania*; typically with numerous radial multiples of 4 or more cells and irregular clusters, with a distinct radial or oblique pattern in some species of *Baccharis* (Fig. 186 H), *Brachylaena* (Fig. 186 I),[1] *Ericameria*, *Flotovia*, *Gochnatia*, *Oliganthes* (2430), and *Senecio*; in tangential rows in *Anaphalis* (1154), *Baccharis*, *Moquinia* (1687), *Proustia*, *Santolina*, *Senecio* (rarely), *Stoebe*, and *Vernonia* (1154); commonly more than 40 per sq. mm., but slightly fewer than 20 per sq. mm. in *Olearia*, *Senecio* p.p., and *Vernonia*, and as few as 2·5 per sq. mm. in *Vernonia javanica* DC.; ring-porous or semi-ring-porous in some species of *Baccharis*, *Flourensia*, *Gochnatia*, *Inula*, *Proustia*, and *Vernonia*; spiral thickening reported to be common in temperate species (1886) and observed in some species of *Baccharis*, *Eupatorium*, *Flotovia*, *Flourensia*, *Proustia*, and *Stoebe*; spiral striations recorded by Solereder as common in several genera. Perforations typically simple and only slightly oblique. Th. Hartig, Sanio, Smith (2148), Solereder, and Tangl have described multiperforate plates of an unusual type, circular in outline and placed horizontally; the plates vary from scalariform to reticulate, with the perforations arranged in various directions and often curved. These perforation plates occur together with simple perforations and have been reported in *Ageratum*, *Albertinia*, *Berkheya*, *Calea*, *Cichorium*, *Cullumia*, *Echinops*, *Helianthus*, *Hieracium*, *Lychnophora*, *Sonchus*, *Tripteris*, and *Zalu-*

---

[1] In the 2 species of *Brachylaena* from Madagascar illustrated by Lecomte (1332), the radial pattern is much less pronounced in *B. merana* (Baker) Humb. (*Synchodendrum*) and the vessels show a tangential arrangement in *B. ramiflora* (DC.) Humb. (*Vernonia*) (1812).

zania. Intervascular pitting alternate, sometimes horizontally elongated or with confluent apertures in *Eupatorium* and *Senecio*, minute in *Brachylaena*, *Eupatorium* p.p., and *Vernonia*; pits to ray and wood parenchyma usually similar to the intervascular pitting; larger, elongated pits present in some species of *Senecio*, *Vernonia*, and *Wedelia*. Solid deposits moderately common to abundant in *Anaphalis* (1154), *Brachylaena*, *Flourensia*, *Gochnatia*, *Moquinia* (1687), *Olearia*, *Senecio* p.p., and *Tessaria* (2430). Mean member length 0·2–0·3 mm. **Parenchyma** often sparse and seldom abundant; typically paratracheal, with a few cells to a complete sheath round the vessels, sometimes locally confluent where the vessels tend to a tangential arrangement, e.g. in *Proustia* and *Vernonia*, very rarely slightly aliform, e.g. in *Vernonia arborea* Buch-Ham var. *javanica* Koord. et Valet; limited to occasional cells touching the vessels in *Brachylaena* p.p., *Flotovia*, *Gochnatia*, and *Santolina*, with a few short apotracheal bands in addition to vasicentric in *Anaphalis* (1154) and *Olearia* (525); Perrot (1694) illustrates numerous scattered cells in addition to scanty paratracheal in *Vernonia merana* Baker; in occasional groups mixed with numerous minute vessels in *Inula* and *Santolina*; in broad bands in *Stoebe* and *Wedelia*; in short uniseriate rows in *Cnicothamnus* (312). Typically without contents. Strands most commonly of 1–2 cells, with numerous fusiform cells in some species of *Baccharis*, *Flourensia*, *Olearia*, *Proustia*, and *Senecio*, and almost entirely of fusiform cells in *Stoebe*, but of 2–4 or 6 cells in species of *Eupatorium*, *Faujasia*, *Stenopadus*, and *Vernonia*. Storied in some species of *Artemisia* (1851), *Baccharis*, *Bigelowia* (1851), *Brachylaena*, *Hymenoclea* (1851), *Olearia*, *Proustia*, and *Senecio*. With chambered, solitary crystals in *Ericameria*. **Rays** typically 4–10 cells wide, up to 18 cells wide in *Eupatorium* and *Inula*, exclusively uniseriate or with only occasional biseriate rays in *Brachylaena* p.p., *Gochnatia*, *Moquinia* (312), and *Stenopadus*; without rays in *Santolina chamaecyparissus* Linn. and with only an occasional, very large ray in *Stoebe*; rays sometimes more than 1 mm. high, e.g. in *Artemisia*, *Dubautia* (282), *Eupatorium*, *Inula*, *Piptocarpha*, *Tessaria* (312), and *Vernonia* p.p. and often showing evidence of dissection into smaller units; woods with multiseriate rays typically with few or very low (often only 1 or 2 cells high) uniseriate rays, but uniseriate rays more numerous in *Ericameria*, *Flotovia*, and *Inula*; uniseriate rays composed of mixed procumbent and upright cells or, as in *Senecio* and *Vernonia*, almost entirely of upright cells; mostly 5–11 rays per mm., fewer than 4 per mm. in *Eupatorium*, *Faujasia*, *Flourensia*, *Mikania*, *Senecio* (most species), and *Vernonia* (a few species), 12–15 per mm. in *Brachylaena* and *Gochnatia*; multiseriate rays typically composed of an irregular mixture of square or upright cells and procumbent cells, with upright sheath cells on the margins (Fig. 186 A); tending to a more uniform central distribution of the procumbent cells and with distinct marginal rows of square or upright cells in *Ericameria*, *Faujasia* (Fig. 186 F), *Flotovia*, *Flourensia*, *Piptocarpha*, *Proustia*, and *Wedelia*; sheath cells present in several genera but sometimes not very distinct; homogeneous (Kribs's Type III) in *Brachylaena* and *Gochnatia*, and with rays composed entirely of square to upright cells in *Dubautia* (282) and *Stenopadus*. Distinctive contents rare, crystals present in *Ericameria* and *Proustia*, those of the latter numerous, long-shaped and often more than 1 per cell (Fig. 186 C). Storied in *Brachylaena* and *Gochnatia*. **Fibres** typically with small simple pits, or the pits with very small borders (1154), usually more numerous on the radial than on the tangential walls, distinctly bordered in *Ericameria parishii* Hall; occasionally with a few thin septa, e.g. in some species of *Eupatorium*, *Faujasia*, *Raillardia* (2158), *Senecio* (2158), *Verbesina* (2158), and *Vernonia*; walls usually thick, sometimes very thick, e.g. in *Brachylaena*, *Flourensia*, and *Stenopadus*, very thin in *Vernonia javanica* DC. Spiral thickening reported in *Anaphalis sordida* Boerl. (1154). Mean length 0·5–1·4 mm. **Vasicentric tracheids** observed in *Wedelia* and reported (1497) in *Brachylaena*. **Intercellular canals** reported by Webber (2377) in the rays of *Artemisia tridentata* Nutt., *Chrysothamnus nauseosus* (Pall.) Brit., and *Hymenoclea salsola* T. et G. **Growth Rings.** Seasonal activity of the cambium in *Pluchea indica* Less. in Java has been investigated by Coster (481). **Interxylary cork** layers recorded in *Artemisia tridentata* Nutt. (1886). (See also under 'Anomalous Secondary Thickening', below, and 'Ecological Anatomy' on p. 797.)

ANOMALOUS SECONDARY THICKENING

Xylem divided into narrow plates by broad primary and secondary rays in *Bidens rubifolia* H. B. et K. and in species of *Mikania* according to Solereder. Wedges of xylem in the phloem also stated to occur in the same plants. A broad secondary zone of xylem and phloem of pericyclic origin also recorded in *Mikania*.

Adamson (3) refers to anomalous secondary thickening in a few genera of Inuleae, including the sub-tribes Relhaniinae and Gnaphalinae. The primary bundles in the genera concerned include no cambium. In *Phaenocoma* the structure is at first normal, but a supplementary cambium arises later on. A cambial zone, formed around the original vascular cylinder, gives rise to xylem and islands of phloem in *Disparago*, *Elytropappus*, and *Stoebe*. The phloem is lignified in the genera examined by Adamson (see also under 'Phloem' above, p. 789). Adamson also refers to successive concentric rings of vascular bundles in *Metalasia*, a feature previously recorded by Solereder as arising in the phloem of the initial vascular ring in *Kleinia*. Solereder also mentions similar bundles laid down in the endodermal region at the base of the stem of *Dahlia imperialis* Roezl., and concentric rings of vascular bundles in the root of *Atractylis gummifera* Linn. More recently, Adamson (5) has described anomalous secondary thickening initiated from pericyclic cambia in the stem and root of 3 species of *Osteospermum*. The successive rings are in the form of continuous, concentric cylinders in *O. moniliferum* Linn., but appear as separate strands in *O. ciliatum* Berg. and *O. subulatum* DC. In *O. ciliatum*, anomalous thickening is confined to the persistent, basal parts of the stem, whilst inversely orientated strands are laid down between successive zones in rapidly growing stems of the same species. Adamson suggests that there may be a relation between anomalous structure and the woody habit, but this is difficult to understand in view of the numerous woody members of the family in which secondary thickening proceeds normally.

The formation of **interxylary cork** in various, mostly shrubby species of *Artemisia* has been investigated by Moss (1565) (see also 'Ecological Anatomy', p. 798, and 'Wood', above). In the herbaceous *A. dracunculoides* Pursh., interxylary cork is formed only in the perennating, underground portions.

Diettert (588) has also described the formation of interxylary cork in *Artemisia tridentata* Nutt.

Intraxylary phloem is stated by Mullan (1571) to occur in the stem of *Launea pinnatifida* Cass., and was observed at Kew near the protoxylem of most of the vascular bundles of *Lactuca virosa* Linn. In the light of Worsdell's observations described above, it seems probable that the intraxylary phloem represents all that remains of ancestral medullary bundles.

RHIZOMES AND ROOTSTOCKS

The vertical stem of *Taraxacum officinale* Weber is short and complex in structure. The anatomy of the more elongated vertical stems, which sometimes arise in the same species from adventitious buds well below the level of the soil, has been described by Curtis (516), Fritsché (726), and Guir and Burress (844) as showing a ring of vascular bundles separated by prominent medullary rays, accompanied by collateral and centric leaf trace bundles and by strands of sieve and laticiferous tissue in the cortex. According to Curtis the 'crown' of *Taraxacum officinale* becomes divided after arcs of secondary cambium, formed within the central cylinder, have united with the primary cambium at a lower level in the crown, thus causing the isolation of separate xylem masses. The secondary steles thus formed become completely separated from each other by the formation of cork in the secondary phloem. Division of the 'crown' occurs before or after the terminal inflorescence grows in length. A similar course of events occurs also in *Taraxacum kok-saghyz* Rodin (see 'Economic Uses') according to Bulgakov (308), who has pointed out that this provides a natural mechanism for vegetative propagation.

The rhizome of *Megalodonta beckii* (Torrey) Greene has been described by Hoeck (983) as containing a ring of open, collateral, vascular bundles; a few fibres being present on the outside of the phloem, and occasional latex tubes in the cortex.

ROOT

Primary vascular structure of *Helianthus annuus* Linn. diarch, but becoming triarch or tetrarch at higher levels in this species according to Thiel (2246). Primary structure tetrarch in *Balsamorhiza sagittata* Nutt. according to Faust (674).

The root and rootstock of *Taraxacum officinale* Weber have been investigated by Curtis (516), Fritsché (726), and Guir and Burress (844). Primary structure diarch. Central part of the mature root occupied by a core of xylem, including numerous vessels. Tissue surrounding the xylem mostly consisting of secondary phloem, built up of parenchyma, with concentrically arranged strands of sieve tubes and articulated laticiferous vessels embedded in it, the sieve tubes and laticiferous elements being difficult to distinguish without resorting to special staining methods. Cork at first formed superficially, but phellogen developing in the phloem later on.

The following facts concerning the root anatomy of *Launea pinnatifida* Cass. have been recorded by Mullan (1571). Cork arising in the pericycle. Secondary phloem well developed, the sieve tubes and laticiferous elements being arranged more or less radially and separated by dilation of the medullary rays and conjunctive tissue. Crystal-sand and oil present in the cortex, and sphaerites in cells surrounding the groups of laticiferous elements.

Articulated laticiferous tubes in the root of *Krigia virginica* Willd. first appear on the inside of the protophloem according to Holm (990). A system of endodermal ducts also occurs in the same species, a feature said by Holm to have been previously recorded only in *Scolymus*, *Scorzonera*, and *Tragopogon*.

Roots of the aquatic *Megalondonta beckii* (Torrey) Greene described by Hoeck (983) as containing a series of radiately arranged intercellular spaces, the pentarch stele being surrounded by a well-defined endodermis; a single latex tube containing a brownish, somewhat resinous substance present outside each phloem strand.

Thin roots with uniformly triarch structure and thicker ones which are tetrarch or pentarch said by Majumdar (1420) to arise from the same nodes in *Enhydra fluctuans* Lour.

The roots of the arboreal Senecios (see also under 'Arboreal Senecios and Espeletias', p. 791, and 'Ecological Anatomy', below) which grow on Kilimanjaro, when examined by Hare (890) were found to be wholly adventitious. Some of the roots of the mature plant are thin, hard, and fibrous and consist mostly of a solid core of xylem surrounded by a protective layer of periderm. These roots, on which root hairs were not observed, are described as purely mechanical in function. Other roots, which are thick, soft, and succulent, have a central pith surrounded by a radiate xylem which appears stellate in transverse sections, with broad medullary rays between the arms. The bulk of the succulent roots consists of a cortex which never becomes exfoliated by the development of pericyclic cork, the outer surface being protected by thickening of the peripheral cells. Mycorrhiza also become established in the peripheral tissues. Other features noted in the succulent roots included their primary pentarch structure, their abundant root hairs, and a conspicuous endodermis with persistent casparian thickenings.

In view of Hare's observations on the occurrence of root hairs in the arboreal Senecios, it is interesting to note that Whitaker (2418) found that the root hairs in some members of the Compositae persist for as much as 3 years. The hairy portion of permanently hirsute roots may be general or limited to the basal region of the root system. Root hairs generally disappear when secondary thickening begins, but, in some instances, root hairs are absent from roots in which no secondary thickening occurs. It follows that persistent root hairs are more frequent in herbaceous than in woody species. Roots of 2 distinct kinds have also been described in '*Thrincia* (*Leontodon*) *tuberosa* DC.' by Nicolas (1590). In this species, enlargement of the fusiform roots occurs in meristematic areas which surround some of the xylem vessels.

Tetley (2243) refers to the formation of patches or complete cylinders of exogenous cork in the roots of a few species of *Achillea*, *Arctotis*, *Artemisia*, *Cosmos*, and *Olearia*.

ECOLOGICAL ANATOMY

Hare's (890) important work on the ecological anatomy of the arboreal Senecios from Kilimanjaro (see also under 'Arboreal Senecios and Espeletias', p. 791, and 'Root', above) has shown that the leaf structure of species at successively higher altitudes on the mountain exhibit a corresponding series of increasingly xeromorphic characters. With increasing altitude, the cells of the epidermis become smaller, the aerating tissues more compact with smaller but more numerous intercellular spaces, the stomatal frequency becomes higher and the hairy covering denser. The leaf, in all of the species examined, is provided with conspicuous oil ducts, whilst secretory hairs and hydathodes occur even at the highest altitudinal range.

Senecio praecox DC. is an interesting stem succulent of which the structure has been described by Reiche (1907). A stem with a total diameter of 10 cm. shows a pith 3 cm. in diameter, an irregular xylem about 2·5 cm. broad, and a green parenchymatous cortex about 1 cm. broad. The sappy, green pith becomes hollow apart from transverse septa. The hard wood of the xylem includes wide but short vessel members and paratracheal parenchyma, the ground tissue consisting mainly of short, thick-walled fibres. The tall and wide medullary rays are composed of large, pitted cells. Phloem strands are well developed; the endodermis is conspicuous as an amyliferous layer; cortical vascular bundles are present; no sclerenchyma was noted in the cortex apart from slight lignification in the region of the phloem of old stems; numerous lenticels were observed. The roots are fleshy, and the assimilatory tissue of the leaf very variable in response to differences of light intensity.

Senecio longiflorus Sch., another stem succulent species which occurs in South-West Africa, is characterized, according to Zemke (2505), by a small pith, surrounded by a ring of separate vascular bundles, the outer part of the broad fleshy cortex consisting of palisade chlorenchyma. There are 25 somewhat sunken stomata per sq. mm. of stem surface.

In the ericoid leaves of *Pertya phylicoides* J. F. Jeffrey, narrow canals were observed by Briquet (273) in the inner part of the outer cell walls. Briquet suggests that the canals may serve for the introduction into the cells of substances necessary for the formation of cutin, without the mechanical properties of the epidermal layer being impaired. The formation of interxylary cork (see 'Anomalous Secondary Thickening') in certain species of *Artemisia* was interpreted by Moss (1565) as a xerophytic character. The submerged aquatic *Megalodonta beckii* (Torrey) Greene has been described by Hoeck (983) (see also under 'Root').

It is impossible to summarize all the facts which have been recorded concerning the ecological anatomy of various other members of the Compositae, but it may be noted that the following genera and species have been investigated by the authors mentioned.

Brachycome sinclairii Hook. f., *Cassinia vauvilliersii* Hook. f. var. *rubra* Buch., *Celmisia longifolia* Cass. var. *gracilenta* T. Kirk, *Gnaphalium traversii* Hook. f., *Helichrysum bellidioides* Willd., *Olearia virgata* Hook. f., and *Senecio bellidioides* Hook. f. by Betts (190); *Senecio magnificus* F. v. Muell. by Wood (2458); *Raoulia* spp. (with polymorphic and ecologically specialized leaves) by Foweraker (703); *Taraxacum officinale* Weber by Curtis (516) and Guir and Burress (844); *Launea pinnatifida* Cass. by Mullan (1571); '*Townsendia exscapa* Porter' by Bunton (309); species of *Gazania*, *Helichrysum*, and *Tripteris* by Zemke (2505).

PHYLOGENETIC AND TAXONOMIC NOTES

Moss (1565), who examined the formation of interxylary cork in certain species of ***Artemisia***, points out that this unusual tissue occurs chiefly in species with specialized floral structure, and expresses the opinion that this character should be taken into account when future revisions of the genus are made.

Various members of the Compositae have been studied in investigations into the phylogenetic relationships of trees and herbs. This subject is dealt with more fully in one of the introductory chapters (p. xxxiv). In this connexion, it may be noted that Whitaker (2417, 2418) has pointed out that *Solidago* includes relatively woody and herbaceous species, the latter being regarded as derived from the former by reduction of the amount of vascular tissue in association with outgoing leaf traces. As already indicated (p. xxxviii) this interpretation is open to question. Whitaker also holds that the intraxylary phloem of the leaf trace bundles in *Solidago* is a relic of a type of structure which was formerly characteristic of the cauline bundles as well. This conception falls into line with Worsdell's (2471) view that the medullary bundles of the Compositae (see p. 789) represent vestiges of an ancestral system of scattered bundles.

Small (2132) has published a series of papers concerning the phylogeny of the Compositae, summarizing his views in the article just cited.

Janssonius comments on the wide differences in wood structure between the varieties of *Vernonia arborea* Buch.-Ham.

ECONOMIC USES

Many members of the Compositae are cultivated for ornamental purposes. These include such well-known plants as asters, chrysanthemums, dahlias, heleniums and the so-called everlasting plants from South Africa belonging to the genus *Helichrysum* and its allies. The comparative anatomy of 2 cultivated dahlias has recently been described by Coutière-Trannoy and Chevalier (488).

Edible plants include the Jerusalem artichoke (*Helianthus tuberosus* Linn.), of which the tubers are eaten. According to Reed (1898) the edible tubers of this species consist of the parenchyma of the medullary rays and pith, together with the xylem. The globe artichoke, of which the fleshy parts of the inflorescence are eaten, is *Cynara scolymus* Pers. The roots of scorzonera (*Scorzonera hispanica* Linn.) and salsify (*Tragopogon porrifolius* Linn.) are used to a limited extent as vegetables. The lettuce (*Lactuca scariola* Linn.) is a familiar salad plant, whilst the blanched leaves of chicory (*Cichorium intybus* Linn.) are used for the same purpose. The large, fleshy roots of chicory are also employed, after roasting and grinding, in admixture with coffee, whilst the roots of the dandelion (*Taraxacum officinale* Weber) sometimes constitute an adulterant of coffee and are also used to a limited extent in medicine. The dried roots of dandelion and chicory are not easy to distinguish when finely ground, but, in transverse sections of dandelion, the concentric zones of laticiferous and sieve tubes and the small cylindrical core of xylem contrast with the more irregularly distributed laticiferous and sieve elements and the rayed structure of the xylem in chicory. The recognition of these 2 materials is sometimes of considerable economic importance. An hereditary stem fasciation in chicory has been described by Stout (2210).

Selected, early maturing varieties of the sunflower (*Helianthus annuus* Linn.) are now widely cultivated for the sake of their oily seeds. Pyrethrum flowers

(*Chrysanthemum cinerariaefolium* Vis.) are important as the source of a well-known insecticide.

Although many Compositae contain latex, no member of the family is well established as a commercial source of rubber. This is because the yield of rubber is small and the quality poor in comparison with those of the Para rubber tree (*Hevea brasiliensis* Müll.-Arg., Family Euphorbiaceae, see p. 1231). Other difficulties are connected with cultivation, or the extraction of the latex in commercial quantities. Nevertheless, in times of economic stress or war, much attention has been devoted to investigating the possibility of obtaining rubber from members of the Compositae. Thus, during the Second World War, the rubber content and cultivation of the Russian plant known as kok-saghyz (*Taraxacum kok-saghyz* Rodin) were investigated at different centres in many parts of the world, including Kew. The rubber in this species occurs chiefly in the laticiferous vessels in the secondary phloem of the root. Although the dry roots contain on an average about 10 per cent. of rubber of reasonably good quality, the low yield per acre and the high cost of cultivation exclude the possibility of using it in most parts of the world under existing economic conditions.

An interesting anatomical problem connected with this species is the question of whether large or small rooted plants yield the most rubber. Rudenskaja (1965) has shown that, as the root increases in diameter, the number of laticiferous vessels per unit area of transverse section decreases. On the other hand, the total number of laticiferous vessels in each section increases as the root grows larger. Another important point noted by Rudenskaja is that the roots which are richest in rubber are those which possess the widest latex vessels. From these facts it was concluded that, in selecting high yielding strains, it is desirable to work with large roots having wide latex vessels and not merely to select for diameter of root alone. This subject has been followed up by Nichiporovich, Ostapenko, and Vassiljeva (1589), who claim to have demonstrated that tetraploid forms have thicker roots, a wider secondary cortex, larger parenchymatous cells, and, to a lesser degree, wider latex vessels than those of diploid plants. The same authors concluded that, in consequence of these anatomical characteristics, polyploid strains have a higher total yield but a lower percentage rubber content than diploid forms. Further details have been recorded, amongst other investigators, by Mashtakov (1454) and Bugalkov (308). (See also under 'Root' on p. 796.)

Another interesting anatomical feature of kok-saghyz is that, at certain intervals during its life, a large part of the laticiferous and other external tissues of the root is cut off by a cork cambium, in such a way that it fits loosely, like a glove on a finger, over the inner tissues. When this happens the 'glove' is easily detached if the plant is pulled up, and a large part of the rubber is thereby lost. Cultural methods to avoid this loss are necessary when the plant is grown on a commercial scale.

The related krym-saghyz (*Taraxacum megalorhizon* H. Maz.) and Tau-saghyz (*Scorzonera tau-saghyz* Lipsch. et Bossé), which also aroused interest in Russia on account of their rubber content, have since proved less promising than kok-saghyz.

Guayule (*Parthenium argentatum* Gray), a small shrub from Mexico, which has been cultivated in suitable parts of the U.S.A. and elsewhere, has also been investigated as a source of rubber, which has been extracted commercially to a limited extent. The anatomy of Guayule has been examined by Ross (1958), who paid particular attention to the secretory canals and the formation of rubber. The rubber is produced chiefly in the cells of the primary and secondary cortex of the stem and to some extent in the medullary rays. Very little is formed in the leaves. The primary secretory canals originate schizogenously at the growing-point, and occur opposite the vascular bundles in the primary cortex and pith of the stem. The canals accompany the vascular bundles in the leaf, one being present above and below each of the larger vascular strands, but there is only one on the adaxial side of each of the smaller bundles. Primary canals also occur in the cortex of the root. The secondary canals, which are likewise schizogenous, are arranged in concentric rings in the phloem. The well-developed cork, composed of thin-walled cells, arises in the outer part of the cortex. All young parts of the plant are densely covered with short-stalked, T-shaped hairs.

The anatomy of *Parthenium argentatum* has been more fully examined by Lloyd (1381) and Artschwager (43), its physiology studied by Mitchell, Whiting, and Benedict (1541), whilst Addicot (6) has shown how the leaves become detached mechanically when they die at a break which passes through a weak abscission zone. Artschwager has described the structure of the seedling as well as that of the mature plant. A large proportion of the stem at the time of harvesting consists of xylem with narrow, poorly defined growth rings. The small pith seldom exceeds 0·4 mm. in diameter, and may become sclerotic in old stems. Most of the tissue outside the xylem consists of secondary phloem, with vestiges of primary cortex, the exterior being protected by a corky layer which shows deep notches in transverse sections and irregular fissures in surface view. The periderm is usually thin in specimens having a high rubber content. Artschwager, like earlier workers, refers to irregular concentric layers of fibres and resin canals alternating with one another in the secondary phloem. The roots are yellow and show shallow longitudinal fissures. In transverse section they exhibit a hard, pithless, woody core, a broad cortex and a massive fissured periderm. Some of the roots are fibrous and lack periderm, but are provided with a dense covering of long-persistent root hairs. The resin canals in the secondary phloem of old roots are often reduced to slits. The leaves, which vary in shape, have a mesophyll consisting chiefly of palisade cells. Discussing structure in relation to rubber production, Artschwager says: 'It is necessary to know the varieties anatomically before attempting to interpret the effect of environment on structure. Since rubber storage appears to be related to structure, varieties with greater storage space for rubber would furnish better raw material for selective breeding work than would varieties in which the secondary cortex is thin, even though both varieties might test high in percentage of rubber.'

Astrov (47) states that the varieties of *Parthenium argentatum* to which he refers as *angustifolium* Nic. and *latifolium* Nic. have numerous large secretory canals in the cortex and pith, and a cortex which is more fully developed than the slightly lignified secondary phloem These varieties are stated to yield more rubber than those referred to as *deltoideum* Nic., *marioloides* Nic., and *prostratum* Astrov, in which the cortex is less, but the secondary xylem more fully developed. Astrov also refers to a third group of varieties of which the structure is intermediate in character, but for which the rubber content has not been established.

The possibility of using chrysil (*Chrysothamnus nauseosus* (Pall.) Brit.) as a source of rubber has been investigated, but this material has never been used in large quantities. The rubber content, morphology, and other features of the plant have been fully described by Hall and Goodspeed (872), who demonstrated that the rubber, like that of Guayule, is present within the individual cells of the plant, and is not a latex rubber. According to Hall and Goodspeed, the rubber, which occurs chiefly in the parenchymatous elements of the cortex, but is absent from all parts of the mature xylem, is not easily detected by histological methods in plants less than 3–4 years old. Some attention has also been devoted in North America to obtaining rubber from the goldenrods (*Solidago* spp.).

Many Compositae have been used in medicine at one time or another, but only a few are now of any importance, except as herbal remedies. Those which are still important include chamomile flowers (*Anthemis nobilis* Linn.), for which *Matricaria chamomilla* Linn. and *Chrysanthemum parthenium* Bernh. have sometimes been substituted; arnica flowers and rhizome (*Arnica montana* Linn.); marigold flowers (*Calendula officinalis* Linn.); pellitory or pyrethrum root (*Anacyclus pyrethrum* DC.), for which the root of *Corrigiola littoralis* Linn. (Family Caryophyllaceae, see p. 152) has sometimes been substituted; santonica or wormseed, which consists of the young, dried capitula of *Artemisia cina* Berg., and absinthium or wormwood consisting of the dried flowering tops of *Artemisia absinthium* Linn. The morphology and chemistry of species of *Artemisia* which are used in medicine have been investigated by Wallis (2347), and a detailed article on the Indian species published by Quazilbash (1764) and another dealing solely with *Artemisia tridentata* Nutt. by Diettert (588). Detailed microscopical observations on numerous species of *Artemisia* have also been described by Obermeyer (1625). Apart from microscopical details of the flower, variation in the following features of the stem and leaf were found by Obermeyer to be of specific diagnostic value. For the stem, the distribution of the sub-epidermal collenchyma in the ribs and grooves; the presence or absence of secretory cavities; the amount and distribution of fibre in the pericycle; the occurrence of separate vascular bundles or of a closed vascular ring. For the leaf, the surface view of the epidermis; the morphology and distribution of the hairs; the structure of the midrib; the presence or absence of secretory canals and of clustered or solitary crystals of calcium oxalate. Secretory canals usually present just internal to, or immediately on the outside of, the endodermis; present in the pith of the stem as well in *A. absinthium* Linn. but not in the other species examined by Obermeyer.

Other microscopical details concerning members of the Compositae which are of minor medicinal importance or which are or have been used as herbal remedies or as adulterants for more important drugs have been recorded as follows. Holm (1031, 1048, 1065, 1072), North American species; Gattiker (752), species of *Antennaria*, *Gnaphalium*, and *Helichrysum*; Weiss (2393), miscellaneous species.

The genus *Brachylaena* is the source of some scented timbers in East

Africa, which are sometimes substituted for Sandalwood, and which are used locally for furniture. *Olearia argophylla* F. v. M. is highly esteemed for fine cabinet work in Australia.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Achillea,* Achyropappus, Actinolepis, Actinomeris,* Adenostemma, Adenostyles, Ageratum,* Ainsliaea, Albertinia, Ambrosia,* Amellus,* Ammobium, Anacyclus,* Anaphalis,* Andryala,* Antennaria, Anthemis, Aplopappus,* Arctium,* Arctotis,* Arnica,* Artemisia,* Aster,* Athanasia, Atractylis, Baccharis,* Baeria,* Balsamorhiza, Baltimora, Barnadesia,* Bellis, Bidens,* Blanchetia, Bothriocline, Brachycome,* Brachylaena, Brickellia,* Cacalia, Calendula, Callistephus,* Calocephalus, Cardopatium, Carduus,* Carlina,* Carthamnus,* Cassinia,* Celmisia, Cenia,* Centaurea,* Centauropsis, Cephalophora, Chaetanthera, Chaptalia, Chardinia, Charieis,* Chondrilla,* Chrysanthemum,* Chrysothamnus, Chuquiraga, Cichorium,* Cineraria, Cirsium,* Cnicus, Coreopsis,* Cosmos,* Cousinia, Crepis,* Cryptostemma, Cynara, Dahlia,* Dicoma, Dimorphotheca,* Disparago, Doronicum,* Echinacea,* Echinops,* Elephantopus, Elytropappus, Emilia,* Enhydra, Eremanthus, Erigeron,* Eriocephalus,* Erlangea,* Espeletia,* Ethulia, Eupatorium,* Evax, Felicia,* Filago, Flaveria, Gaillardia,* Galactites, Galinsoga,* Gazania,* Gerbera, Gnaphalium, Gochnatia, Grindelia, Guizotia, Gundelia, Gynura,* Haplopappus, Haplostephium, Helenium,* Helianthus,* Helichrysum, Heliopsis, Helipterum,* Hieracium,* Hofmeisteria, Humea, Hyalis, Hymenonema, Hymenoxys, Hyoseris, Ifloga, Inula,* Iva, Jasonia,* Jurinea, Kleinia, Krigia, Lactuca,* Lapsana,* Launea, Layia,* Leontodon, Leontopodium, Lepidophyllum, Leptosyne,* Leria, Leyssera, Liatris,* Lindheimera, Lonas, Lucilia, Lychnophora, Lycoseris, Madia, Matricaria, Megalodonta, Metalasia, Micropus, Moquinia, Mulgedium, Mutisia, Nassauvia, Odontospermum, Olearia,* Oliganthes, Onopordon,* Onoseris, Osteospermum, Pacourina, Pallenis, Parthenium, Pectis, Pegolettia, Pertya, Phaenocoma, Phagnalon, Picridium,* Picris,* Piptocarpha, Piptolepis, Pithecoseris, Podachaenium, Podolepis, Podotheca, Polyachyrus, Polymnia, Porophyllum, Proustia, Pulicaria, Pyrethrum, Pyrrhopappus, Raoulia, Rodigia, Rolandra, Rudbeckia,* Santolina,* Sanvitalia,* Saussurea,* Schlectendalia, Scolymus,* Scorzonera, Senecio,* Sericocarpus,* Serratula,* Silphium,* Silybum, Soaresia, Solidago,* Sonchus, Spilanthes, Staehelina, Stifftia,* Stoebe, Symphyopappus, Tagetes,* Tanacetum,* Taraxacum,* Tarchonanthus, Telmatophila, Thrincia, Townsendia, Tragopogon,* Tridax, Tripteris, Triptilion, Urospermum, Ursinea,* Vanillosmopsis, Venidium,* Vernonia, Warionia, Wedelia, Xanthium,* Xeranthemum,* Zaluzania, Zexmenia, Zinnia, Zollikoferia.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

(Anaphalis), Artemisia, Baccharis, (Berkheya), (Bigelowia), Brachylaena, (Cassinia), (Chrysothamnus), (Cnicothamnus), Ericameria, Eupatorium, Faujasia, Flotovia, Flourensia, Gochnatia, (Helichrysum), (Hymenoclea), Inula, (Mikania), (Moquinia), Olearia, (Oliganthes), Piptocarpha, Proustia, (Raillardia), Santolina, Senecio, Stenopadus, Stoebe, (Tessaria), (Verbesina), Vernonia, Wedelia.

LITERATURE

(i) *On General Anatomy*

Adamson **3, 5,** Addicot **6,** Alexandrov **12, 15,** Alexandrov and Alexandrova **18,** Artschwager **43,** Astrov **47,** Barratt **143,** Benoist **172,** Betts **190,** Biddulph **195,** Boodle **231,** Briquet **273,** Bulgakov **308,** Bunton **309,** Casparis **345,** Chainaye **347,** Cotton **482,** Coutière-Trannoy and Chevalier **488,** Curtis **516,** Diettert **588,** Esau **661,** Faust **674,** Foweraker **703,** Fritsché **726,** Gattiker **752,** Graf **801,** Guir and Burress **844,** Hall and Goodspeed **872,** Hanausek **880,** Hare **890,** Hart **911,** Hayek **926,** Hess **958,** Hoeck **983,** Holm **990, 1031, 1048, 1065, 1072,** Humbert **1107, 1108,** Jeuch **2524,** Juillet, Galavielle, and Ancelin **1202,** Kienholz **1236,** Klug **1247,** Lloyd **1381,** Majumdar **1420,** Marvin **1451,** Mashtakov **1454,** Mitchell, Whiting, and Benedict **1541,** Moss **1565,** Mullan **1571,** Neithammer **1585,** Nichiporovich, Ostapenko, and Vassiljeva **1589,** Nicolas **1590,** Obermeyer **1625,** Priestley and Scott **1753,** Quazilbash **1764,** Quentin **1765,** Reed **1898,** Reiche **1907,** Ross **1958,** Rudenskaja **1965,** Sabnis **1977,** Small **2132,** Smith, A. C. and Koch **2142,** Smith, G. E. **2148,** Stadler **2180,** Starr **2188,** Stout **2210,** Tetley **2243,** Thiel **2246,** Thoday **2250,** Thompson **2254,** Wall **2346,** Wallis **2347,** Weiss **2393,** Werner **2414,** Whitaker **2417, 2418,** Wood, J. G. **2458,** Woodhead **2463,** Worsdell **2471,** Zemke **2505.**

(ii) *On Wood Structure*

Beekman **167,** den Berger **179,** Betts **188, 189,** Brown, F.B.H. **282,** Burgerstein **312,** Coster **481,** Cozzo **492, 494,** Dadswell **525,** Howard **1088,** Humbert **1107,** Janssonius **1154,** Kanehira **1209,** Lecomte **1332, 1334,** Metcalfe **1497,** Pereira **1687,** Perrot **1694,** Pfeiffer, H. **1712,** Preston **1740,** Priestley and Scott **1753,** Record **1780, 1781, 1783, 1794, 1809, 1812, 1843, 1851,** Record and Hess **1886,** Record and Mell **1894,** Smith **2148,** Thompson **2254,** Webber **2377,** Williams **2430.**

169. STYLIDIACEAE

(FIG. 188 on p. 818)

SUMMARY

A small, mainly herbaceous family, in which the habit varies somewhat in different genera. The family occurs in Australasia, Tropical Asia, and Antarctic South America. *Stylidium* possesses a basal rosette of grass-like leaves, the flowers being borne on a scape. *Donatia* and *Phyllachne* are moss-like herbs with small, overlapping, adpressed leaves, the small flowers being situated between those towards the apex of the short axis. The creeping or erect stems of *Forstera* also bear small, overlapping leaves, but the flowers occur on a small, leafless peduncle. *Oreostylidium* is a small, stemless rosette plant. *Levenhookia* consists of small annuals of which the stem is branched in the inflorescence region. *Stylidium* exhibits several anatomical peculiarities, especially the oblique, overlapping cells of the leaf **epidermis** which occur in some, but not in all, species. The peculiar and somewhat varied structure of the **scape** in this genus is also noteworthy. The chief reserve food substance is **inulin.** The anatomy of the family has been described in some detail by Mildbraed (1532), on whose account the following description is mainly based, except for reference to *Stylidium graminifolium* Swartz cultivated at Kew, and the account of *Donatia novae-zelandiae* Hook. f. published by Chandler (377).

LEAF

(i) *Stylidium*

Glandular **hairs** with multicellular stalks of varying length and bicellular or multicellular heads recorded in a number of species. Some of the glandular hairs secrete mucilage. The grass-like basal leaves of *Stylidium graminifolium* Swartz (Fig. 188 B), cultivated at Kew, exhibit the following features. Dorsiventral, with 2 or 3 layers of short, arm-palisade cells, the greater part of the **mesophyll** consisting of very lacunar spongy tissue, including numerous idioblasts, the latter appearing somewhat elongated in longitudinal sections of the leaf and filled with unidentified, somewhat granular contents. **Vascular bundles** embedded in the mesophyll, arranged in the middle part of the leaf in a dorso-ventrally flattened circle; all very small except the median one towards the upper surface; each bundle surrounded by a very distinct, parenchymatous sheath. Vascular bundles towards the base of the leaf more irregularly distributed.

According to Mildbraed (1532), *Stylidium saxifragoides* Lindl. and related species differ from *S. graminifolium* chiefly in having, on both surfaces, what appears in transverse sections as a **multi-layered epidermis** consisting of thick-walled cells. Longitudinal sections reveal this epidermis as a single row of obliquely arranged, overlapping, very elongated cells (in some instances resembling fibres). The oblique epidermal cells, especially those towards the leaf margin, bear lateral papillae or teeth, standing erect from the leaf surface, particularly in the *Squamosae* section of the genus. **Stomata** in species with this peculiar type of epidermis confined to special strips of the leaf surface provided with epidermal cells of the normal type. Mesophyll generally consisting wholly of spongy parenchyma.

(ii) *Forstera*

Mildbraed has recorded the following leaf structure in *Forstera sedifolia* Linn. Upper **epidermis** composed of isodiametric cells with brown (tanniniferous?) contents, the outer wall being strongly thickened and differentiated into several layers. Lower epidermis with a broad keel-like strip composed of similar cells, but with **stomata** situated on either side. Epidermal cells at the leaf margin more elongated, provided with thicker walls, and obliquely orientated. Median bundle ending near the leaf apex in a large **hydathode.**

(iii) *Donatia*

Chandler (377) has recorded the following information concerning *Donatia novae-zelandiae* Hook. f. Leaves small, dorsally adpressed. Base triangular in transverse section, with 1 central vascular bundle embedded in homogeneous parenchyma. Leaf oval in section in the middle part, and supplied by 3 vascular bundles. Palisade tissue developed only towards the leaf apex. **Stomata** confined to the lower surface, and most abundant towards the apex; ranunculaceous, and hence apparently differing in this respect from those of *D. megellanica* Lam. described by Solereder as rubiaceous. **Mucilage cells** abundant in the mesophyll.

AXIS

STEM

Chandler (377) has recorded the following information concerning *Donatia novae-zelandiae* Hook. f. **Cork** composed of rectangular cells filled with oily, granular contents. Long, silky **hairs,** arising directly from the outermost layer of cork cells, form a dense matting at the base of the closely adpressed leaves; each hair bayonet-pointed and provided with perforated, oblique septa. An epiphytic **fungus** recorded amongst the hairs. **Cortex** composed of round cells of uniform size. **Endodermis** distinct, consisting of oblong, thickened cells with granular contents. **Phloem** in the form of strands. **Xylem** including spiral, reticulate, and annular tracheids and vessels with simple perforations. **Pith** relatively small; composed of large, slightly thickened cells. **Resinous material,** recorded by Solereder in the intercellular spaces of the primary cortex of *Donatia megellanica* Lam., not observed by Chandler in *D. novae-zelandiae*. Mildbraed (1532) records the occurrence of continuous circles of xylem and phloem in *Donatia*, *Forstera*, and *Phyllachne*, the vessels in these genera being arranged in short radial rows.

SCAPE

The following structure was observed in the scape of *Stylidium graminifolium* Swartz (Fig. 188 E) examined at Kew. **Cortex** very narrow, consisting of about 3 layers of parenchymatous cells. A broad zone of sclerenchyma present on the inside of the cortex, with a few **vascular bundles** embedded in the inner part of it. An irregular circle of widely spaced vascular strands occurs at the inner periphery of the sclerenchymatous zone. **Xylem** including small vessels, mostly with spiral thickening, but a few with bordered pits. Central ground tissue consisting of very spongy parenchyma, breaking down and tending to become hollow. **Secretory elements** present in the form of numerous (tanniniferous?) idioblasts with granular contents, scattered amongst the cells of the central ground tissue.

Mildbraed (l.c.) has described the same type of structure in *S. saxifragoides* Lindl., and a similar vascular supply but with the bundles variously orientated in numerous species of *Stylidium*, particularly in the section *Rhynchangium* as well as in *S. appressum* Benth., *S. repens* R.Br., and *S. streptocarpum* Sond. The same author has also recorded a somewhat different arrangement in *S. scandens* R.Br. Vascular tissue in this species forming a continuous circle with the separate bundles not easily distinguishable. Primary vessels provided with spiral or annular thickening and arranged in scattered groups. Phloem present in the form of a complex system of strands more towards the periphery of the axis, the tissue between the phloem strands and the groups of primary vessels consisting of relatively large, pitted vessels accompanied by parenchyma. The whole vascular system is bounded externally by a ring of strongly thickened mechanical elements, followed, towards the exterior, by an endodermis and cortical parenchyma. Pith in the same species consisting of pitted cells.

TAXONOMIC NOTES

Chandler (377), when discussing the taxonomy of the Stylidiaceae, agreed with Mildbraed (1532) that the position of the family within the Campanulatae is assured. At the same time he doubted whether the family, as constituted by Mildbraed, is a natural group, and furthermore whether it is to be regarded as a small independent branch of the Campanulatae which has arisen in the Antarctic. This taxonomic problem cannot readily be solved from a study of the anatomical structure, because the plants are highly specialized, and members of the various genera somewhat diverse in habit.

GENERA DESCRIBED

Donatia, Forstera, Phyllachne, Stylidium.*

* Represented in the Kew slide collection.

LITERATURE

On General Anatomy

Chandler 377, Mildbraed 1532.

170. GOODENIACEAE

(INCLUDING BRUNONIACEAE)

SUMMARY

(i) GENERAL

The Goodeniaceae consists of herbs and shrublets, some of which show xeromorphic characters such as fleshy leaves which include well-developed water-storage tissue. The leaves of *Anthotium* are rush-like. The family occurs chiefly in Australia, whilst certain genera are to be found in New Zealand, Tropical Asia, and Antarctic America. The **hairs** include various glandular and non-glandular types. **Sclerenchymatous idioblasts,** which are sometimes branched, are common in the **mesophyll** of the leaf and sometimes occur in the cortex of the stem as well. The vascular bundles of the veins are rather infrequently accompanied by sclerenchyma, sheaths of parenchyma or collenchyma being more common. In the stem the **vascular system** is much less well developed in the herbaceous *Goodenia* than in the more woody genera *Dampiera*, *Leschenaultia*, and *Scaevola.* The vessels, at least in the woody species, are provided with simple perforations. **Medullary bundles,** which represent leaf traces, occur in certain genera. Clustered and solitary **crystals** common but sparse.

(ii) WOOD STRUCTURE

Vessels solitary, perforations simple, members moderately short. **Parenchyma** vasicentric and diffuse. **Rays** up to 7 cells wide, high, heterogeneous. **Fibres** with bordered pits; of medium length.

LEAF

Dorsiventral, isobilateral, or centric, the structure varying within the individual genera. Dorsiventral structure recorded, e.g. by Solereder in *Dampiera brownii* F. Muell. and by Kienholz (1236) in *Scaevola frutescens* (Mill.) Krause, but centric in *Scaevola plumieri* (L.) Vahl. **Hairs** glandular and non-glandular, varying considerably in form. Non-glandular hairs include very short, unicellular, conical types in several species of *Goodenia* including *G. ovata* Smith and in *Scaevola revoluta* R.Br.; dendroid, with opposite pairs of arms in *Dampiera brownii* and other species of *Dampiera.* Short-stalked, peltate glands recorded in *Goodenia ovata*, *Scaevola crassifolia* Labill., and *S. plumieri.* Peltate, resin-secreting glands of *S. crassifolia* described in detail by Collins (452) and said to be particularly numerous on buds and young leaves. Glands with uniseriate stalks bearing a few-celled, ellipsoidal head recorded in *Calogyne berardiana* (Gaudich) F. Muell. Various types of glandular hairs also occur in most of the other genera. **Epidermis,** especially in xerophytic species and above all in *Leschenaultia*, composed of much thickened cells. Groups of silicified cells in and below the epidermis recorded by Solereder in *Dampiera brownii.* **Stomata** present on both surfaces or confined to the lower side; ranunculaceous in most genera and species, but rubiaceous stomata, with 2 of the 4 surrounding cells lying parallel to the pore, recorded in *Brunonia.* Stomata sunken in some species but not in others.

Mesophyll including 1–2, less frequently 3 or even more, rows of palisade cells. Palisade cells elongated, e.g., in *Leschenaultia*, but broad and short, e.g., in *Velleia.* Inner part of the mesophyll of species with fleshy leaves largely consisting of water-storage cells, e.g. in *Scaevola plumieri.* Central part of the mesophyll also composed of water-storage cells in *Leschenaultia linarioides* DC. Sclerenchymatous idioblasts fairly common in the mesophyll, those of *Dampiera* often considerably branched. Vascular bundles of the **veins** seldom accompanied by sclerenchyma, but said by Solereder to be accompanied by an arc of sclerenchyma in *Selliera radicans* Cav. Vascular bundles surrounded by a sheath of suberized cells in *Goodenia ovata*; sheathed by a layer of parenchymatous cells devoid of chloroplasts in *Scaevola frutescens* according to Kienholz (1236); surrounded by collenchymatous cells in *Scaevola hookeri* F. Muell. and *S. thesioides* Benth. Cluster and solitary **crystals** commonly, but usually rather sparingly, present in the mesophyll according to Krause (1278). Mucilage cavities recorded by Mullan (1571) in the petiole of *Scaevola plumieri.*

Rush-like leaves of *Anthotium* stated by Krause (1278) to exhibit the following special structure. Elliptical in transverse section, the central part composed of large, thin-walled parenchymatous cells. Vascular bundles arranged in a circle, but larger and more fully developed towards the adaxial than towards the abaxial surface. Somewhat similar centric structure also occurs in *Goodenia arthrotricha* F. Muell. and *G. stelligera* R.Br. For further details concerning leaf structure see Colozza's (453) article.

AXIS

STEM

Outer and lateral walls of the epidermal cells of *Scaevola plumieri* (L.) Vahl. said by Mullan (1571) to be covered with rod-shaped bodies of a waxy nature. **Cork** arising in the sub-epidermis in some species of *Scaevola*, but formed at a deeper level in the cortex in other species of the same genus. Cork of *Scaevola montana* Labill. including stone cells. Primary **cortex** lacunar in *Goodenia ovata* Sm. and *S. plumieri*; including branched, sclerenchymatous idioblasts in *Dampiera fasciculata* R.Br. and certain other species of *Dampiera.* Most herbaceous species, especially of *Goodenia*, exhibit poorly developed **vascular bundles,** mechanical support being provided by a cylinder of thick-walled fibres. Shrubby forms, such as species of *Dampiera*, *Leschenaultia*, and *Scaevola*, have much larger vascular bundles and exhibit more secondary thickening, additional mechanical support being provided externally to the vascular system by strands or a closed ring of fibres, other sclerosed elements sometimes being present in addition to the fibres. Outwardly directed extensions of the mechanical ring observed by Krause (1278) in a few species of the woody genera, those in *Leschenaultia linarioides* DC. appearing, in transverse sections, as girders connecting the epidermis with the main mechanical ring. **Xylem** of the woody species usually in the form of a cylinder traversed by rays mostly 1–2, more rarely 3, cells wide in certain species of *Scaevola*. Rays composed of upright cells, the latter being narrow and provided with fairly thick walls. Vessels, in the woody species, with elliptical or circular simple perforations. Pits to rays cells bordered. Vessels stated by Krause (1278) to be absent from *Scaevola spinescens* R.Br. Wood fibres with bordered pits. Xylem parenchyma scanty. **Medullary bundles,** representing leaf traces, sometimes accompanied by, or embedded in, a tissue of thick-walled parenchymatous cells, recorded in a few species of *Calogyne*, *Goodenia* (especially *G. ovata*), and *Selliera*. Vessels of the medullary bundles of *Goodenia ovata* mostly radially arranged and provided with spiral thickening. Medullary bundles in old stems appear very reduced. **Pith** wide e.g. in *S. frutescens*, the source of taccada pith. Mucilage recorded by Mullan (1571) in the intercellular spaces of the cortex of *Scaevola plumieri*. Cluster and solitary **crystals** said by Krause (1278) to be common but to occur sparingly in the cortex and pith of certain members of the family. For further details concerning stem structure see Colozza's (453) article.

INFLORESCENCE AXIS

Krause (1278) describes the vascular bundles, except in *Velleia* with 2 circles, as usually arranged in a single circle and accompanied externally by a ring of sclerenchyma.

WOOD[1]

Vessels small to medium sized (mean tangential diameter about 100 μ); solitary; 7–10 per sq. mm.; perforations simple; mean member length about 0·32 mm. **Parenchyma** paratracheal, as vasicentric sheaths 1–2 cells wide, and apotracheal, as scattered cells among the fibres. **Rays** up to 7 cells wide and 1–4 mm. high; heterogeneous, composed mostly of upright cells. **Fibres** with bordered pits; about 1 mm. long.

ROOT

The following particulars concerning the root of *Scaevola plumieri* (L.) Vahl. have been recorded by Mullan (1571). First-formed **cork** superficial, but subsequent layers arise in a more deeply seated position. **Endodermis** consisting of cells with suberized walls. **Pith** narrow, composed of pitted cells with lignified walls. Inulin constitutes an important food reserve.

TAXONOMIC NOTES

Krause (1278) points out that the absence of laticiferous canals from the Goodeniaceae serves to distinguish this family from the Lobeliaceae.

GENERA DESCRIBED

Anthotium, Brunonia, Calogyne, Dampiera, Goodenia, Leschenaultia, Scaevola, Selliera, Velleia.

---

[1] Based almost entirely on the description of *Scaevola frutescens* (Mill.) Krause (syn. *S. koenigi* Vahl.) by Kanehira (1206).

LITERATURE

(i) *On General Anatomy*
Collins **452**, Colozza **453**, Kienholz **1236**, Krause **1278**, Mullan **1571**.

(ii) *On Wood Structure*
Kanehira **1206**, Pfeiffer, H. **1712**, Record **1843**, **1851**.

171. CAMPANULACEAE

(FIG. 187 on p. 812)

SUMMARY

(i) GENERAL

A widely distributed family, consisting mainly of herbs, but some species are shrubs or small trees. Various specialized types of leaf structure, some of which are described below, occur amongst xerophilous species. The **hairs** are mostly unicellular, and may be calcified or silicified. One of the most important diagnostic characters is the widespread occurrence of **laticiferous elements,** mostly in the phloem of both leaf and stem. Variously distributed and orientated **medullary bundles** occur in a number of genera. It is also noteworthy that **medullary cork** has been recorded in *Campanula*. The **mesophyll** of the leaf sometimes includes arm-palisade cells. Bodies resembling **cystoliths** frequently occur in cells at the bases of the hairs or in the surrounding epidermis. A very detailed account of the anatomy of the leaf in many members of the family has been published by Schmidt (2038). The anatomy of the anomalous genera *Pentaphragma* and *Sphenoclea* is described separately on pp. 814 and 815.

(ii) WOOD

Vessels small, perforations simple, intervascular pitting large and alternate, pits to ray cells often large and elongated. **Parenchyma** absent. **Rays** broad, composed mostly of upright cells. **Fibres** with simple pits, rarely septate.

LEAF

Usually dorsiventral, but various transitional stages between this and centric structure also common; mesophyll sometimes homogeneous. **Hairs** mostly unicellular, showing a considerable range in frequency, length, thickness of the wall, and in the width of the lumina; sometimes raised on pedestals formed from the neighbouring cells; commonly calcified or silicified, especially in *Campanula*. Unicellular hairs usually conical and pointed, but longer hairs with rounded ends recorded by Schmidt (2038) in *Codonopsis*, and short rounded hairs in species of *Adenophora*, *Platycodon*, *Roella*, *Specularia*; ends of the trichomes slightly swollen in *Phyteuma pinnatum* Linn. Uniseriate hairs recorded in *Campanumoea celebica* Blume. Glandular hairs unknown. Bodies resembling cystoliths sometimes occur at the bases of the hairs or in the adjacent epidermal cells, as well as at the leaf margins. **Epidermis** usually composed of rather low, medium-sized cells, with straight or sinuous anticlinal walls; often locally papillose. **Stomata** ranunculaceous; nearly always occurring on both surfaces, but sometimes confined to the lower side. **Pores** of the stomata parallel to the midrib in species with narrow leaves. **Hydathodes** occurring widely, arranged in groups on the upper surface near the margin of the leaf; situated on special prominences of the leaf surface or on the leaf teeth (see also 'Ecological Anatomy' on p. 812). **Hypoderm,** see 'Specialized Leaves' below. **Mesophyll** most frequently including 1 or 2 layers of palisade cells; the latter sometimes short and broad, e.g. in *Wahlenbergia gracilia* Schrad. Arm-palisade cells recorded by Schmidt (2038) in certain species of *Adenophora*, *Campanula*, *Campanumoea*, *Canarina*, *Cephalostigma*, *Codonopsis*, *Heterocodon*, *Jasione*, *Leptocodon*, *Musschia*, *Ostrowskia*, *Peracarpa*, *Platycodon*, *Prismatocarpus*, *Symphyandra*, *Wahlenbergia*. Spongy tissue, composed of hypha-like cells and permeated with large intercellular spaces, in several species of *Lightfootia*. Vascular bundles of the **veins** seldom accompanied by sclerenchyma, especially on the same side as the phloem, but fibres in the xylem region recorded by Schmidt (2038) in species of *Lightfootia*, *Microcodon*, *Prismatocarpus*, *Rhigiophyllum*, *Wahlenbergia*. Vascular bundles frequently surrounded by sheaths of large parenchymatous cells, e.g. in species of *Prismatocarpus* and *Rhigiophyllum*.

Petiole, in transverse sections through the distal end of material cultivated at Kew, exhibiting an open, crescent-shaped, median vascular strand in species of *Adenophora* and *Codonopsis* (Fig. 187 F); a deeper crescent with incurved ends, e.g. in *Cyananthus* (Fig. 187 D) and *Symphyandra* (Fig. 187 E); a strand in the form of a cylinder, flattened or slightly concave towards the adaxial surface, the last-named part of the bundle sometimes consisting wholly or mainly of phloem, in *Asyneuma* (Fig. 187 C), *Campanula*, *Phyteuma*, *Symphyandra*. Additional bundles in the wings noted in *Asyneuma* and *Phyteuma* (Fig. 187 A). **Laticiferous canals** believed to be universally present, mostly confined to the phloem of the vascular bundles, but branches extending into the mesophyll recorded in *Canarina*. Fine, mostly acicular **crystals** recorded in the epidermis and mesophyll of *Canarina*, *Hedraeanthus*, *Heterochaenia*, *Leptocodon* (cluster crystals), *Phyteuma*; probably occurring in other genera as well but easily overlooked. Yellowish sphaerocrystals, of unknown chemical composition, said to have been demonstrated in species of *Adenophora*, *Asyneuma*, *Campanula*, *Canarina*, *Musschia*, *Phyteuma*, *Specularia*, *Symphyandra*, *Trachelium*.

SPECIALIZED LEAVES

The upper **epidermis** of species of *Merciera*, *Microcodon*, *Roella*, and *Wahlenbergia* endemic to South Africa, consists, in the middle of the leaf surface, of cells with wide lumina and straight anticlinal walls; the cells showing a progressive decrease in size towards the margin.

Transverse sections of the 4-sided leaf of *Wahlenbergia prostrata* E. Mey. exhibit a crescent of aqueous tissue beneath the upper epidermis bounded below first by a spongy tissue and then by a single palisade layer. Structure somewhat similar in *W. capillacea* DC. A fibrous **hypoderm,** either in the form of crescent-shaped masses at the leaf margins, or extending somewhat over the upper surface of the leaf, recorded in the acicular leaves of certain xerophilous species of *Cephalostigma*, *Lightfootia*, *Merciera*, *Microcodon*, *Prismatocarpus*, *Roella*, *Wahlenbergia* from South Africa. Sclerenchyma sometimes occurs on the lower side of the midrib in these genera.

Ecological Anatomy

Stomata of *Campanula rotundifolia* Linn. according to Rea (1774) more numerous on the upper surface of leaves towards the apex of the shoot than in the corresponding position in more basal leaves. The stomatal frequency on the lower surface is increased by strong illumination and a dry atmosphere. The size of individual stomata also varies according to the environmental conditions. Groups of **hydathodes** on the upper surface in the same species are more numerous on basal than on apical leaves. Rea concluded that habitat

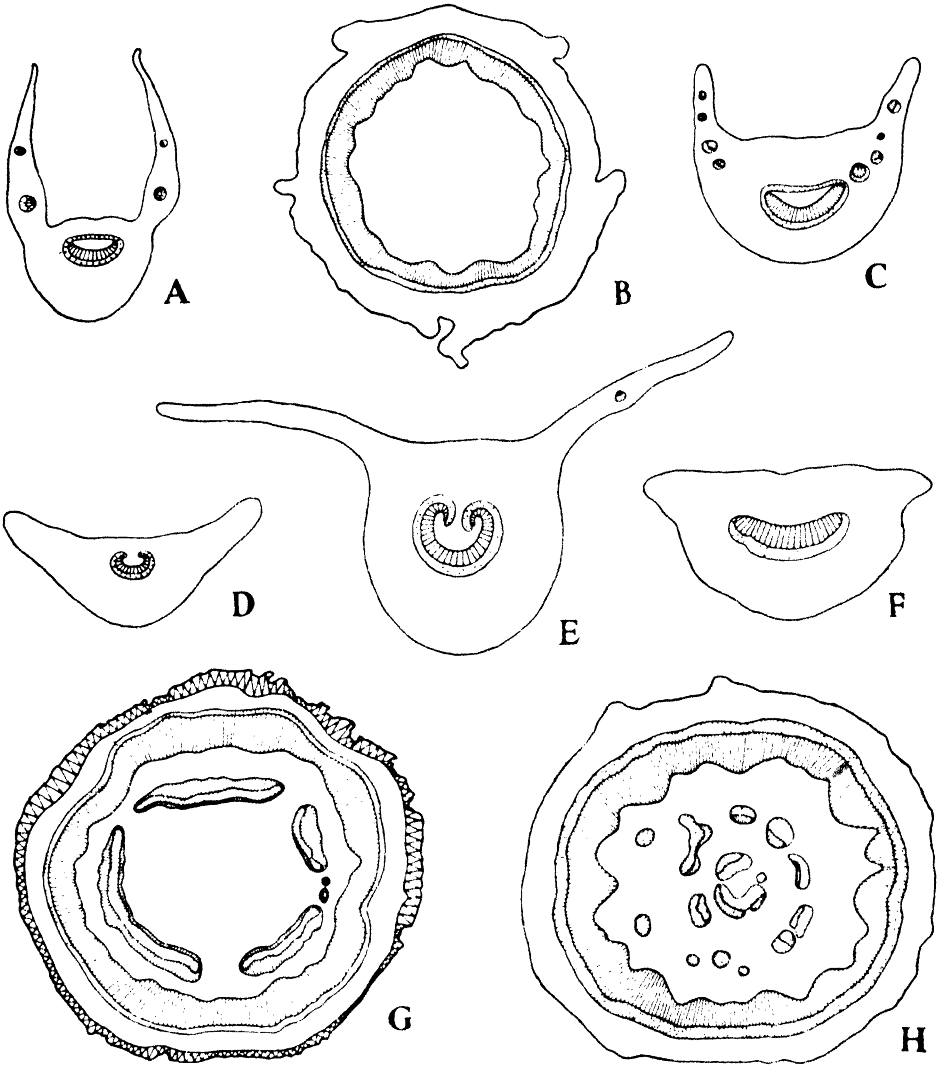


Fig. 187. *CAMPANULACEAE*

A, *Phyteuma campanuloides* Bieb. Petiole × 19. B, *Jasione perennis* Lam. Stem × 19. C, *Asyneuma limonifolium* Bornm. Petiole × 19. D, *Cyananthus lobatus* Wall. Petiole × 19. E, *Symphyandra hofmanni* Pant. Petiole × 19. F, *Codonopsis viridiflora* Maxim. Petiole × 33. G. *Campanula pyramidalis* Linn. Stem × 5. H, *Asyneuma limonifolium* Bornm. Stem × 28.

conditions, the position of the leaves on the shoot, and the development of the vascular system determine the frequency of hydathodes. Tenopyr (2241) found that the leaves towards the apex of the stem of *Campanula rotundifolia* are composed of smaller cells than those towards the base. This principle was found to apply in other unrelated plants as well.

AXIS

STEM (Fig. 187 B, G, and H)

Cork seldom developed, but noted arising in various positions ranging from the sub-epidermis to the inner cortex in old stems of *Campanula pyramidalis* Linn. A clearly defined **endodermis,** sometimes with casparian thickenings, noted in a few species of *Asyneuma* and *Campanula* and recorded by Betts (189) in *Wahlenbergia.* **Pericycle** generally devoid of sclerenchyma, but a ring of fibres noted in *Platycodon.* **Xylem** in species of *Adenophora, Asyneuma* (Fig. 187 H), *Campanula* (Fig. 187 G), *Codonopsis, Cyananthus, Jasione* (Fig. 187 B), *Phyteuma, Platycodon, Symphyandra* examined at Kew forming a continuous cylinder even in young stems; including vessels with simple perforations except in *Platycodon* where scalariform plates occur; few-barred scalariform perforation plates also recorded in *Lightfootia* and *Roella.* **Cortical vascular bundles** said to occur in *Campanula pyramidalis.* **Medullary bundles,** consisting of xylem and phloem or of phloem alone, recorded or observed in certain species of *Asyneuma* (Fig. 187 H), *Campanula* (Fig. 187 G), *Hedraeanthus, Michauxia, Phyteuma, Symphyandra, Wahlenbergia,* but not universally present in these genera. The position and number of the medullary bundles show considerable variation in different species of *Campanula.* The individual medullary bundles in this genus sometimes collateral and inversely orientated; occasionally isolated, but frequently anastomosed or even forming a closed ring. Bundles centric with central phloem in some of the species. Inversely orientated medullary bundles also occur in a few species of *Asyneuma, Campanula, Michauxia, Phyteuma.* **Medullary cork,** arising on the inside of the inversely orientated medullary bundles, recorded in *Campanula pyramidalis* and at the periphery of the central ring of medullary bundles in *Phyteuma limonifolium* Sibh. et Sm. **Laticiferous canals** recorded or observed in the inner part of the phloem of species of *Adenophora, Asyneuma, Campanula, Codonopsis, Cyananthus, Phyteuma, Platycodon, Symphyandra, Wahlenbergia,* and probably occurring in most genera (see also under 'Leaf'). **Fasciated stems** of *Campanula carpatica* Jacq. described by Worsdell (2472).

WOOD[1]

Vessels small (mean tangential diameter less than 100 μ); solitary and in small radial multiples and clusters; perforations simple; intervascular pitting rather large, alternate, sometimes elongated; pits to ray cells large and irregular in shape. **Parenchyma** absent or indistinct. **Rays** broad and composed of large upright cells, which in *Clermontia* are not always clearly distinct from the fibres in tangential sections. **Fibres** with simple or indistinctly bordered pits; rarely septate; walls thin.

---

[1] Based almost entirely on the description of *Clermontia* and *Wahlenbergia* by Record and Hess (1886).

ANOMALOUS GENERA

(i) PENTAPHRAGMA

(This genus has recently been given the status of a new family, the Pentaphragmataceae, by Airy-Shaw, 9.)

The following particulars refer especially to *P. begoniaefolium* (Roxb. ex Jack) Wall. and *P. ellipticum* Poulsen.

LEAF

Dorsiventral. **Hairs** long, with 2 or more uniseriate branches arising from a very short pedestal, mostly on the lower side of the leaf, particularly around the midrib. The branches more or less parallel to the leaf surface. **Stomata** chiefly on the lower surface but present on the upper side as well, especially near the marginal leaf-teeth; mostly surrounded by a ring of 3 or occasionally 4 cells, the latter not very different from those of the remainder of the epidermis. An outer but less distinct ring of subsidiary cells also observed in some instances. **Epidermis** composed of cells with straight or slightly sinuous anticlinal walls. **Mesophyll,** according to Schmidt (2038), including a single layer of long palisade cells, but, according to Poulsen's (1736) statement and from observations made on rather badly preserved herbarium specimens at Kew, the palisade tissue is not well developed. Arm-palisade cells recorded by Poulsen in *P. ellipticum*. Vascular bundles of the **veins** not accompanied by sclerenchyma. **Petiole.** Transverse sections through the distal end of specimens from the Kew herbarium exhibit a deep, narrow crescent of widely spaced vascular bundles, accompanied on the inside by a second crescent of, and a few scattered, very small vascular strands. **Secretory elements.** Segmented laticiferous canals recorded by Schmidt in the phloem of the larger vascular bundles, but none seen in the rather badly preserved herbarium specimens examined at Kew.

AXIS

STEM

Epidermis composed of shallow cells. **Cortex** consisting of loose, somewhat elongated chlorenchymatous cells. **Endodermis** very distinct, consisting for the most part of thin-walled cells but provided with casparian thickenings on the inner part of the radial walls. **Phloem** and **xylem** appearing in transverse sections as continuous rings, and traversed by medullary rays 1–2 cells wide, composed of large parenchymatous cells. Xylem including rather numerous, somewhat angular vessels, up to about 60 μ in radial diameter and mostly arranged in radial rows. Vessels in mature wood provided with scalariform lateral pitting, and transitions between this and horizontal bordered pits; perforation plates scalariform. Spiral thickening noted in vessels of young stems. Wood fibres consisting of rectangular elements with moderately thickened walls, wide lumina and conspicuous bordered pits. **Pith** wide, composed of uniform cells. **Laticiferous elements** absent according to Poulsen (1736) and none observed in badly preserved herbarium material examined at Kew.

ROOT

Secondary growth starting very early and serving to obscure the primary structure. An **exodermis** of corky cells present immediately within the collapsed epidermis. Primary **cortex** composed of large clear cells with small intercellular spaces. **Endodermis** consisting of cells of unequal size with casparian thickenings on the inner and radial walls. **Xylem** pentarch.

(ii) SPHENOCLEA

(Family Sphenocleaceae, see 'Taxonomic Notes')

The following description is based on authentically named spirit material of *S. zeylanicum* Gaertn. examined at Kew. The external appearance and habit of this species show a striking resemblance to those of *Phytolacca*, but the raphides which are a very constant and characteristic feature of *Phytolacca* are absent from *Sphenoclea*.

LEAF

Dorsiventral. **Epidermis** on both surfaces papillose. **Stomata** numerous on the lower and occasional on the upper surface; most of those on the lower surface are surrounded by 4 epidermal cells, 2 being parallel and 2 at right angles to the guard cells. **Mesophyll** with 1–2 layers of palisade cells. **Petiole** with a wide, shallow, arc-shaped vascular strand, not supported by sclerenchyma. Vessels of the petiolar xylem oval in transverse section, mostly solitary, but some tending to be in radial multiples. **Air canals,** similar to, but smaller than, those in the cortex of the stem, present below the epidermis and towards the adaxial surface of the petiole. Cluster **crystals** infrequent to numerous in the cortical region of the petiole, and occasional in the mesophyll.

AXIS

STEM

Primary **cortex** including large intercellular **air canals,** mostly separated from one another by single or double rows of parenchymatous cells. Wider parenchymatous portions with smaller canals in them occur between some of the larger canals. **Pericycle** including rather inconspicuous strands of fibres with wide lumina and fairly thin walls. **Xylem** and **phloem** constituting continuous cylinders traversed by medullary rays 1–2 cells wide. An additional, almost complete ring of xylem noted in the pith in transverse sections of old stems, but only in certain specimens. Vessels thin-walled, somewhat angular; rather irregularly distributed; solitary, in radial multiples of up to 10 or more elements, or sometimes in more irregular clusters. Vessels in the secondary xylem with rather large, horizontal, bordered pits in the lateral walls and simple perforations in the end walls. Groundwork of the xylem composed of radial rows of thin-walled fibres with conspicuously bordered pits, mostly appearing rectangular in transverse sections. **Pith** composed of loose, thin-walled parenchyma; becoming hollow. Cluster **crystals** fairly numerous, especially in the air canals in the cortex and in the cells around the central cavity of the pith. Occasional **secretory cells** with translucent contents noted in the pith. **Laticiferous elements.** No typical laticiferous canals noted in the phloem, but occasional, rather wide, elongated cells filled with granular contents which were observed in the phloem may be laticiferous.

TAXONOMIC NOTES

Pentaphragma, which has recently been placed by Airy-Shaw (9) in a new family, the Pentaphragmataceae, differs from the Campanulaceae in several respects, notably in having branched hairs, and stomata surrounded by 3 epidermal cells, whilst in the axis the xylem includes vessels with scalariform lateral pitting and perforation plates. It would be interesting to determine, from adequately preserved material, whether laticiferous canals occur in this genus; none were seen in the herbarium material examined at Kew. According to Schmidt's (2038) account, now confirmed by fresh investigations at Kew, *Sphenoclea* differs somewhat from the Campanulaceae. In particular it disagrees in having rather characteristic stomata which are not typically ranunculaceous (see 'Leaf'); in the presence of pericyclic sclerenchyma in the stem; in the absence of typical laticiferous canals from the phloem, although occasional elongated cells with granular contents situated in the phloem may represent dried latex; in the presence of cluster crystals instead of the fine, mostly acicular crystals which are characteristic of the Campanulaceae. It has already been pointed out that, in general appearance and habit, *Sphenoclea* at once recalls *Phytolacca*, from which it differs, however, in the absence of the characteristic raphides. In the opinion of Mr. H. K. Airy-Shaw, who has recently investigated the taxonomic position of *Sphenoclea*, there are ample reasons for restoring the family Sphenocleaceae to include this genus.

The Lobeliaceae, classified in the Bentham and Hooker system under Campanulaceae, have here been treated as a distinct family.

ECONOMIC USES

The family includes no plants of economic importance apart from those which are cultivated for ornamental purposes.

GENERA DESCRIBED

Adenophora,* Asyneuma,* Campanula,* Campanumoea, Canarina, Cephalostigma, Codonopsis,* Cyananthus,* Hedraeanthus, Heterochaenia, Heterocodon, Jasione,* Leptocodon, Lightfootia, Merciera, Michauxia, Microcodon, Musschia, Ostrowskia, Pentaphragma, Peracarpa, Phyteuma,* Platycodon,* Prismatocarpus, Rhigiophyllum, Roella, Specularia, Sphenoclea, Symphyandra,* Trachelium, Wahlenbergia.*

* Represented in the Kew slide collection

LITERATURE

(i) *On General Anatomy*

Airy-Shaw **9**, Betts **189**, Poulsen **1736**, Rea **1774**, Schmidt, H. **2038**, Tenopyr **2241**, Worsdell **2472**.

(ii) *On Wood Structure*

Dadswell and Record **533**, Kanehira **1209**, Pfeiffer, H **1712**, Record **1843**, **1851**, Record and Hess **1886**.

172. LOBELIACEAE

(FIG. 188 on p. 818)

SUMMARY

(i) GENERAL

A chiefly tropical and sub-tropical family consisting mainly of herbs, but a few species of *Lobelia* are shrubby or even arboreal. The 'tree' lobelias of the African mountains are very interesting members of the family, both from the anatomical and biological standpoints, and a special account of them is given on p. 819. A complex **laticiferous system**, which is situated mainly in the phloem of the leaf and axis but has branches extending into the other tissues as well, is characteristic of many genera and probably occurs throughout the family. The general absence of sclerenchyma from the **pericycle** of the axis and from around the vascular bundles of the leaf veins is another noteworthy feature. The **xylem** and **phloem** of the stem nearly always form a continuous cylinder, whilst the somewhat angular vessels, especially in the primary xylem, tend to be radially arranged. **Crystals** infrequent; none observed in many species.

(ii) WOOD

Vessels small, perforations simple, intervascular pitting alternate, rather large. **Parenchyma** scanty paratracheal. **Rays** 4–15, mostly 4–8, cells wide, high, markedly heterogeneous. **Fibres** with simple pits.

LEAF

Dorsiventral or centric. **Hairs** mostly thin-walled, unicellular or occasionally uniseriate in *Isotoma*, *Lobelia*, *Pratia*, and *Siphocampylus*. Tufted hairs with a multiseriate stalk recorded in *Siphocampylus columnae* G. Don. **Stomata** present on both surfaces or confined to the lower side; generally ranunculaceous. **Petiole** examined only in a few species; transverse sections through the distal end in *Centropogon lucyanus* Schoen. (Fig. 188 G) exhibiting a main cylindrical strand, slightly concave towards the adaxial surface, the vessels of the somewhat dissected xylem being in very definite, widely spaced, radial rows; small accessory strands (not shown in the figure) also present in the wings in the same species. Petiole of *Pratia* sp. (Fig. 188 A) with a small, slightly concave, median strand surrounded by a very distinct endodermis. **Laticiferous system** (see also 'Stem'), extending through the phloem in the vascular bundles of the veins. Tenopyr (2241) states that leaves high up on the stem of *Lobelia erinus* Linn. are composed of smaller cells than the basal leaves. (This principle is known to apply also in other, unrelated plants.)

AXIS

STEM (Fig. 188 C, D, F, H, and I)

Cork rarely formed; arising in the sub-epidermis or outer part of the cortex in species of *Apetahia*, *Clermontia*, *Lobelia*, *Siphocampylus*. Primary **cortex** frequently collenchymatous; lacunar in *Downingia* and in aquatic species of *Lobelia*, e.g. *L. dortmanna* Linn. **Endodermis** usually distinct. **Pericycle** seldom including sclerenchyma. **Phloem** and **xylem,** both in herbaceous and arboreal species, forming a closed cylinder, no individual bundles being recognizable (see, however, under 'Rays' below). Vessels, especially in the primary xylem, usually in well-defined radial rows; those in more mature wood, especially in the arboreal species of *Lobelia*, more irregularly distributed; somewhat angular and seldom exceeding 60 μ in radial diameter. Primary vessels generally provided with spiral thickening; later formed vessels, e.g. in species of *Centropogon*, *Lobelia*, *Pratia*, provided with large, horizontal, almost scalariform pitting and transitions between this and circular, bordered pitting. Perforations mostly simple, with oblique walls, but a few scalariform plates noted in *Lobelia gibberoa* Hemsl. and possibly in other species of *Lobelia*. Wood fibres seen to have bordered pits in a few species. Rays generally

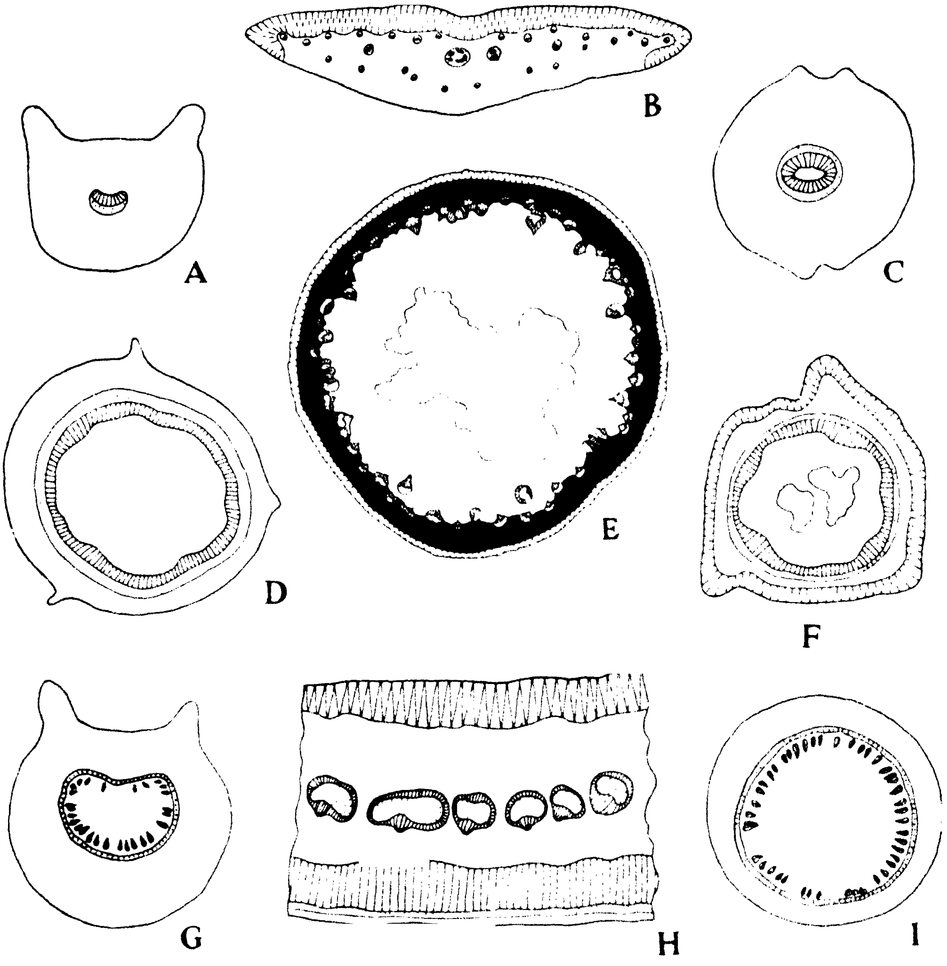


FIG. 188. *LOBELIACEAE*, A, C–D, and F–I; *STYLIDIACEAE*, B and E

A, *Pratia* sp. Petiole × 33. B, *Stylidium graminifolium* Sw. Leaf × 19. C, *Pratia* sp. Stem × 19. D, *Lobelia tupa* Linn. Young stem × 8. E, *Stylidium graminifolium* Sw. Peduncle × 19. F, *Lobelia erinus* Linn. Stem × 19. G, *Centropogon lucyanus* Schoenland. Petiole × 15. H, *Lobelia gibberoa* Hemsl. Portion of old stem × 9. I, *Centropogon lucyanus* Schoenland. Young stem × 12.

inconspicuous and very narrow, but rays 4 cells wide and composed of pitted cells noted in *Lobelia telekii* Schweinf. (For further particulars concerning the vascular system of the arboreal species of *Lobelia* see the special paragraph below.) **Laticiferous vessels** form an anastomosing system in the phloem, and extend by means of branches into other tissues as well, in species of *Centropogon*, *Clermontia*, *Cyanea*, *Delissea*, *Downingia*, *Haynaldia*, *Heterotoma*, *Isotoma*, *Laurentia*, *Lobelia* (Fraser 710), *Piddingtonia*, *Pratia*, *Sclerotheca*, *Siphocampylus*; sometimes extending through the xylem to the pith in *Centropogon*, *Lobelia*, *Siphocampylus*. **Pith** composed of lignified or unlignified cells; sometimes becoming hollow. Spherical or hemispherical clusters of yellowish acicular **crystals** of unknown chemical composition noted in *Pratia* sp.

WOOD[1]

Vessels small (mean tangential diameter less than 100 μ); solitary and in small multiples; mostly not in contact with the rays. Perforations simple, with broad rims. Intervascular pitting alternate, rather large; pits to ray cells similar. **Parenchyma** paratracheal, scanty. Rays mostly 4–8 cells wide and occasionally up to 15 cells; up to 1 cm. high; uniseriates very few; markedly heterogeneous, composed mostly of upright cells, but with some procumbent cells; with sheath cells. **Fibres** with numerous, small, simple pits; walls rather thin and lumina wide.

ROOT

The presence of pitted plates between the cells of the inner, lacunar cortex, and the absence of **root hairs** recorded by Armand (35) in *Lobelia dortmanna* Linn. **Mycorrhizal fungi** in *Lobelia gibbosa* Labill and *L. dentata* Cav. described in detail by Fraser (710). (In these species, fungal hyphae occur in the hypocotyl of young seedlings. In the roots there is a period of fungal invasion, followed by one of fungal enlargement, after which the fungus becomes disorganized.) For root structure in the arboreal *Lobelia rhynchopetalum* see the special section below.

THE ARBOREAL LOBELIAS

The arboreal species of *Lobelia*, which occur in mountainous regions in tropical and sub-tropical Africa, have been the subject of several anatomical investigations, notably those by Hauman (920) and Rosen (1948). *L. rhynchopetalum* (Hochst.) Hemsl. from Abyssinia is a plant with the habit of a large *Dracaena*, with a huge terminal inflorescence. The anatomy of this species has been studied particularly by Rosen (l.c.). The large leaves, especially when immature, bear short, strong trichomes, which serve to keep the individual leaves apart when in the bud. Stomata occur on both surfaces of the leaf. The mesophyll is isobilateral, but with large intercellular spaces amongst the palisade cells towards both surfaces. The vascular strand of the midrib in the lowest part of the leaf appears in transverse sections as a flattened, almost closed, crescent-shaped strand, whilst there are additional, smaller bundles on either side, and a few even less conspicuous ones above the median strand towards the adaxial side of the leaf, and others enclosed within the crescent. At the extreme base of the leaf the median bundle is less compressed. In spite of the large size of the leaves, which must require considerable support, the vascular bundles of the veins, like those of the herbaceous lobelias and other more slender members of the family, are not accompanied by fibres. This indicates that the lack of pericyclic sclerenchyma is a deeply ingrained hereditary character for the family. Inulin constitutes the chief food reserve, although starch was observed by Rosen in the guard cells of the stomata and in the bundle sheath.

---

[1] Based entirely on the description of *Siphocampylus* given by Record and Hess (1886).

In the stem, the fleshy cortex includes a very complex system of vascular bundles with a number of branches extending into the base of each of the crowded leaves, whilst there are other connexions to the main vascular cylinder. Laticiferous canals occur in the phloem of this and other woody species of *Lobelia* in the same way as in herbaceous members of the family. The centre of the stem is occupied by a broad pith which is hollow throughout most of its length. Towards the base of the stem the xylem is more fully developed and the pith narrower. The external covering of the stem consists of a thick layer of cork in which longitudinal fissures develop during secondary thickening. Mechanical elements are lacking, apart from the xylem, which carries the weight of the large terminal inflorescence. The stem structure has been likened to that of the Cycadaceae, but this similarity between a member of an advanced family of the Dicotyledons and the primitive Cycadaceae must evidently be a parallel development.

The rather scanty details concerning the stem structure of *L. wollastoni* Baker recorded by Hauman (l.c.) indicate that this species has points in common with *L. rhynchopetalum*. This applies also to the stem structure of *L. stuhlmannii* Schweinf. and *L. volkensii* Engl. judging from Rosen's (l.c.) account of these species. There are differences, however, particularly in the vascular structure of the leaf bases. Also, in *L. stuhlmannii* and *L. volkensii*, there are large canals lined with a tissue composed of small, thin-walled cells, extending obliquely from the leaf insertions, through the main xylem ring, to the hollow centre of the stem. Rosen suggests that the canals serve for gaseous exchange. Similar canals were noted at Kew in stems of herbarium specimens of *L. gibberoa* Hemsl. (Fig. 188 H). It was impossible to examine them completely in this species owing to the scanty material available, but they appeared to lie parallel to the longitudinal axis of the stem and were embedded in the medullary tissue surrounding the central cavity. In the Kew material, the smaller canals were completely filled with thin-walled tissue, and all of them surrounded by thick-walled fibres with bordered pits, the fibres appearing rectangular in transverse section. It was impossible to determine the morphological nature of these structures because of the scanty material, but their appearance suggested that they may represent centric medullary bundles in which the central phloem breaks down to form a canal. They are shown as centric bundles in Fig. 188 H. If this is so, the peripheral fibres with bordered pits must represent a reduced xylem. That this suggestion is not improbable is indicated by the presence of medullary bundles in some of the closely related Campanulaceae. Similar canals or medullary bundles were not observed at Kew in the woody *L. telekii* Schweinf.

Rosen (l.c.) states that most of the roots of *L. rhynchopetalum* are adventitious in origin, and fleshy, napiform and 3- to 7-arch in structure. The endodermis is at first thickened only on the radial walls of the component cells, but the thickening later extends to the other walls as well. The cortex includes intercellular spaces with thorn-like projections extending into them from the surrounding cells. In the larger roots the cortex also contains numerous small patches of meristematic tissue which give rise to fresh lateral roots.

TAXONOMIC NOTES

The close relationship of the Lobeliaceae to the Campanulaceae is reflected in the many anatomical similarities between the two families.

ECONOMIC USES

Several species of *Lobelia* are cultivated for ornamental purposes, whilst *L. inflata* Linn. possesses a variety of medicinal properties. The hollow stem of this last species, like that of other members of the family, is characterized by a continuous cylinder of xylem. The leaf exhibits an upper epidermis of polygonal, pitted, frequently papillose cells; a lower epidermis composed of cells with more sinuous anticlinal walls; ranunculaceous stomata confined to the lower surface; numerous unicellular or occasionally 2-celled, straight-sided hairs with finely warted or striated cuticle on the lower, and, less frequently, the upper surface of the leaf; a dorsiventral mesophyll, including, especially towards the margin, a single layer of short palisade cells; vascular bundles unaccompanied by sclerenchyma, the smaller ones being completely enclosed in sheaths of large, thin-walled parenchyma; laticiferous canals in the phloem; the absence of crystals; small droplets of oil in the cells of the mesophyll.

GENERA DESCRIBED

Apetahia, Centropogon,* Clermontia, Cyanea, Delissea, Downingia, Haynaldia, Heterotoma, Isotoma, Laurentia, Lobelia,* Piddingtonia, Pratia,* Sclerotheca, Siphocampylus.

* Represented in the Kew slide collection.

LITERATURE

(i) *On General Anatomy*

Armand **35**, Datta and Bell **544**, Fraser **710**, Hauman **920**, Rosen **1948**, Tenopyr **2241**.

(ii) *On Wood Structure*

Kanehira **1209**, Record and Hess **1886**.

173. VACCINIACEAE

(FIG. 189 on p. 824; FIG. 190 on p. 826)

SUMMARY

(i) GENERAL

Mostly small shrubs, often with somewhat leathery leaves. The family occurs on tropical mountains in America and Asia and also in temperate regions. There are not many distinctive anatomical characters for the family, but the ecologically specialized structure of the leaf has been noted by several investigators. The **stomata,** unlike those of Ericaceae, are usually rubiaceous. **Mycorrhiza** occur in certain members of the family, e.g. in *Vaccinium macrocarpum* Ait., where, according to Addoms and Mounce (7), the endophyte occurs throughout the stem system of the plant and extends into the fruits and seeds.

(ii) WOOD

Vessels small and very numerous, usually exclusively solitary, sometimes with spiral thickening, perforation plates all scalariform or mixed scalariform and simple, occasionally foraminate, intervascular pitting rare, opposite to scalariform, pits to parenchyma similar. **Parenchyma** absent or very sparse. **Rays** up to 6–10 cells wide and apparently dissected from very high rays, heterogeneous, often with the central cells square and not procumbent. **Fibres** mostly with distinctly bordered pits; of medium length to moderately short; with a few scattered libriform fibres with simple pits, shorter and often septate.

LEAF

Almost homogeneous in certain species of *Vaccinium*; more often dorsiventral or centric. **Hairs.** Glandular types either (i) consisting of long or short biseriate or multiseriate stalks bearing heads of variable size, e.g. in *Gaylussacia* and *Vaccinium*, or (ii) multicellular, tongue-shaped hairs. These are always bent over parallel to the midrib when situated at the apex of the leaf, and often partly or wholly fused with the epidermis in all of the Thibaudieae as well as in species of *Vaccinium*. Non-glandular hairs mostly uniseriate and varying in the length and thickness of the walls. Disk-shaped, **extra-floral nectaries** with a raised rim recorded at the base of the lamina of *V. teysmannii* Miq. **Cuticle** of very varying thickness and consistency, being especially soft in *Agapetes* or hard and stony in most of the Thibaudieae; with a scaly covering of wax in the Thibaudieae or a white bloom of wax in *V. angustifolium* Benth.; occasionally ridged. Upper **epidermis** exhibiting the following types of structure, believed to be correlated with the environment. (i) Cells flat, with thin walls, e.g. in *V. pennsylvanicum* Lam. and related species. (ii) Cells tall but thin-walled, serving for water storage, in *Gaylussacia* and Vaccinieae of the section *Cyanococcus*. (iii) Cells palisade-like with thick walls in *V. vitis idaea* Linn. and related species. (iv) Cells with spiral or reticulate thickening in *Gaylussacia pinifolia* Ch. et Schl. (v) Cells sclerosed in *Satyria warscewiczii* Klotzsch. **Stomata** usually confined to the lower surface, but recorded on the upper side as well in a few species of *Vaccinium*; generally rubiaceous. The stomata of 4 cultivated varieties of *V. macrocarpum* Ait., examined by Sawyer (2000), showed no differences of taxonomic or functional significance. The average frequency for this species, 632 per sq. mm., recorded by the same author, is claimed to be the highest number known to occur in any plant. **Hypoderm** of various types common beneath the upper epidermis, e.g. in *Cavendishia*, *Ceratostemma*, *Macleania*, *Psammisia*; consisting of several layers in species of *Disterigma*, *Satyria*, *Thibaudia*. **Mesophyll** sometimes including a proportion of water-storage cells with contractile walls. Assimilatory tissue, composed of cells with uniformly thickened walls, recorded in *V. vitis idaea* and related species.

Petiole, in transverse sections through the distal end, exhibiting a single, cylindrical, median vascular bundle in *Agapetes macrantha* Benth. et Hook. (Fig. 189 C), and *Pentapterygium serpens* Klotzsch., and a solitary, very slightly concave strand in *Gaylussacia baccata* K. Koch. (Fig. 189 B), *V. ovatum* Pursh., and *V. vitis idaea* Linn. (Fig. 189 A). **Secretory elements.** Cells with unidentified but probably tanniniferous contents observed in the cortex and phloem of the petiole in species of *Agapetes*, *Gaylussacia*, *Pentapterygium*, *Vaccinium*. Both solitary and clustered **crystals** occur, the latter being more widely distributed. A very detailed account of the leaf anatomy of *V. oxycoccus* L. has been published by Gleisberg (790). Small variations in the leaf structure of *Gaylussacia baccata* K. Koch. and *Vaccinium vacillans* Soland. under different habitat conditions described by Cain and Potzger (328).

AXIS

STEM (Fig. 189 K)

Stem of *Vaccinium* provided with longitudinal ridges especially when young. **Stomata** in *V. myrtilus* Linn., according to Bright (270), confined to the furrows between the ridges, the long axis of the pore lying parallel to that of the stem; rubiaceous. Outer part of the **cortex** in the same species consisting of assimilatory tissue, the peripheral part being more compact than the looser inner tissue which contains aqueous cells, the latter sometimes enclosing clustered crystals. **Cork** said to arise internally to the pericycle fibres in *Vaccinium*, but a sub-epidermal phellogen observed in species of *Agapetes* and *Pentapterygium* (Fig. 189 K). **Pericycle** always containing a continuous or slightly interrupted ring of sclerenchyma in species of *Agapetes*, *Gaylussacia*, *Pentapterygium*, *Vaccinium*. **Xylem** constituting a large proportion of the stem, and forming a continuous cylinder traversed by narrow rays; vessels with exclusively scalariform perforation plates noted in species of *Agapetes*, *Gaylussacia*, *Pentapterygium*, *Vaccinium*; mixed simple perforations and scalariform or reticulate plates also occur. **Pith** of *V. myrtilus* consisting of cells with thick, cellulose walls with simple pits; amyliferous late in the season. **Secretory elements.** Cells (in a few species somewhat elongated and resembling small sacs) with unidentified but probably tanniniferous contents noted in the cortex, phloem, medullary rays, and usually the pith of all of the genera examined at Kew. **Crystals** both solitary and clustered, but the latter most frequent. Solitary crystals seen in species of *Agapetes*, *Pentapterygium*, and *Vaccinium*; clusters observed in species of *Agapetes*, *Gaylussacia*, *Pentapterygium*, *Vaccinium*. **Adventitious roots** arising from the hypocotyl recorded by Bain (101) in seedlings of *V. macrocarpum* Ait. A **mycorrhizal fungus** stated by Addoms and Mounce (7) to occur throughout the stem system of the same species especially in the pith and cortex.

WOOD (Fig. 190 A, E, F)

Vessels typically small (25–50 μ mean tangential diameter), slightly larger in *Paphia* and extremely small (less than 25 μ) in some species of *Vaccinium*; exclusively solitary (apart from apparent tangential pairs due to overlapping ends), but with some clusters in *Agapetes*; mostly 60–100 per sq. mm., more numerous in some species of *Vaccinium* (up to 400); with spiral thickening in

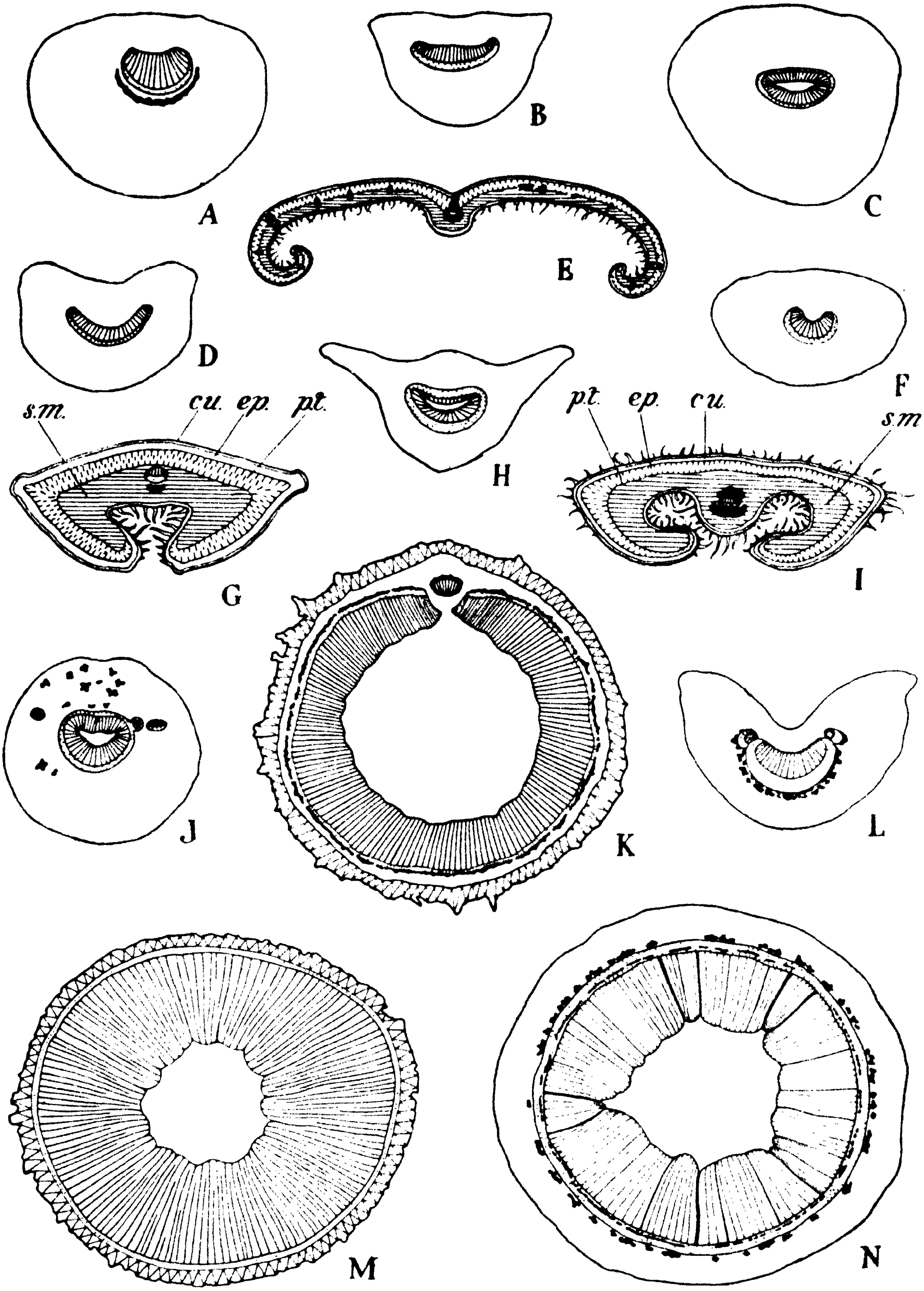


FIG. 189. *VACCINIACEAE*, A–C and K; *ERICACEAE*, D–J and L–N

A, *Vaccinium vitis-idaea* Linn. Petiole × 13. B, *Gaylussacia baccata* K. Koch. Petiole × 13. C, ***Agapetes macrantha*** Benth. et Hook. f. Petiole × 13. D, *Enkianthus pallidiflorus* Craib. Petiole × 28. E, ***Andromeda glaucophylla*** Link. Leaf × 14. F, *Arctostaphylos uva-ursi* (L.) Spreng. Petiole × 28. G, ***Erica cinerea*** Linn. Leaf × 48. H, *Arbutus unedo* Linn. Petiole × 13. I, *Erica tetralix* Linn. Leaf × 48. J, *Rhododendron discolor* Franch. Petiole × 8. K, *Pentapterygium serpens* Klotzsch. Stem × 15. L, *Gaultheria veitchiana* Craib. Petiole × 14. M, *Kalmia angustifolia* Linn. Stem × 19. N, ***Pieris japonica*** D. Don. Stem × 20.

cu. Cuticle. *ep.* Epidermis. *p.t.* Palisade tissue. *s.m.* Spongy mesophyll.

most species of *Vaccinium* and, according to Record (1851), in *Gaylussacia, Pentapterygium*, and *Thibaudia*. Perforation plates most typically both simple and scalariform, the latter with relatively few and wide perforations, perforation plates all scalariform and with more numerous bars (up to 20 or more) in *Psammisia* and some species of *Vaccinium*; with some foraminate plates in most species of *Vaccinium* and often with what appear to be bordered pits mixed with the perforations, and occasionally with scalariform plates with the bars at different angles on the opposite sides of the middle lamella; perforations sometimes all simple in *Agapetes*. Intervascular pitting rare owing to the solitary vessels, either opposite, e.g. in *Macleania*, or scalariform, e.g. in *Vaccinium*; pits to ray parenchyma typically large, scalariform, and simple, tending to be more commonly round, opposite, and bordered in *Vaccinium*. Solid deposits and tyloses sometimes present in *Vaccinium*. Mean member length 0·4–0·75 mm. **Parenchyma** absent or very sparsely scattered among the libriform fibres (apotracheal); occasionally more numerous in *Vaccinium*, e.g. *V. arboreum* Marsh. **Rays** typically of 2 distinct sizes with the larger rays up to 6–10 cells wide, except in *Agapetes* and some species of *Vaccinium*; the larger rays commonly more than 1 mm. high and showing evidence of dissection from very high rays (Fig. 190 A); in some of the species of *Vaccinium*, e.g. *V. arboreum* Marsh., such groups of large rays are infrequent and most of the rays are short and from 1 to 4 cells wide; uniseriate rays moderately high and numerous and composed of high upright cells, except in *Agapetes* and in some species of *Vaccinium*, in which the uniseriate rays are commonly only 1 or 2 cells high; mostly 12–18 rays per mm., sometimes more numerous in *Vaccinium*; heterogeneous, the central part of the large rays composed of large square or slightly upright cells and without truly procumbent cells, except in *Paphia* and *Vaccinium*; usually with 1–4 marginal rows of upright cells, often with more than 10 marginal rows in *Gaylussacia*. Sheath cells usually present, sometimes narrower tangentially than the square central cells, e.g. in *Macleania*; commonly containing gummy deposits and sometimes crystals, either in the ordinary cells or in chambered upright cells, e.g. in *Psammisia pauciflora* Gris. **Fibres** of 2 types. (*a*) The ground tissue of fibre-tracheids, with numerous distinctly bordered pits on all walls and often with thick walls; with spiral thickening in *Vaccinium parvifolium* Sm. and *V. cereum* Forst. f.; mean length 0·7–1·25 mm. (*b*) Scattered among the fibre-tracheids, but particularly round the vessels, a few fibres with small, simple pits and thin walls, often septate, e.g. in *Vaccinium*, and sometimes mixed with a few parenchyma cells; not much longer than the vessel members.

TAXONOMIC NOTES

The family resembles and evidently has close affinities with the Ericaceae.

ECONOMIC USES

The fruits of various species of *Vaccinium* are edible, the most important being the large Cranberry (*V. macrocarpum* Ait.). The small Cranberry (*V. oxycoccus* Linn.) and, in Britain, the native Whortleberry (*V. myrtilus* Linn.) are also used. The Red Whortleberry or Cowberry is derived from *V. vitis idaea* Linn.

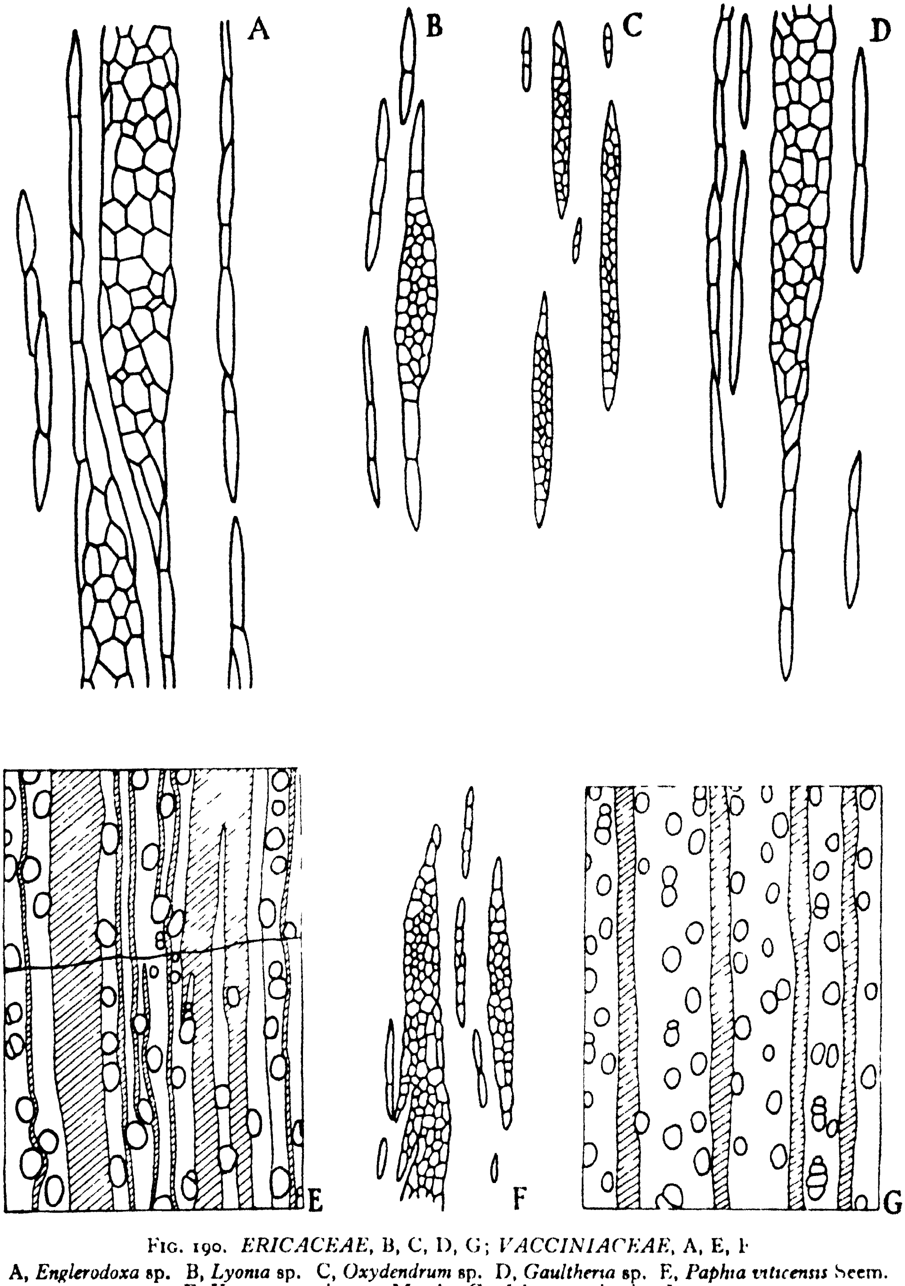


Fig. 190. *ERICACEAE*, B, C, D, G; *VACCINIACEAE*, A, E, F

A, *Englerodoxa* sp. B, *Lyonia* sp. C, *Oxydendrum* sp. D, *Gaultheria* sp. E, *Paphia viticensis* Seem. F, *Vaccinium arboreum* Marsh G, *Arbutus andrachne* Linn.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Agapetes,* Cavendishia, Ceratostema, Disterigma, Gaylussacia,* Macleania, Pentapterygium,* Psammisia, Satyria, Thibaudia, Vaccinium.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Agapetes, Cavendishia, Englerodoxa, Gaylussacia, Macleania, Paphia, (Pentapterygium), Psammisia, (Thibaudia), Vaccinium.

LITERATURE

(i) *On General Anatomy*

Addoms and Mounce **7,** Bain **101,** Bright **270,** Cain and Potzger **328,** Camp **334,** Flint **687,** Gleisberg **790,** Sawyer **2000.**

(ii) *On Wood Structure*

Dadswell and Record **533,** Flint **687,** Janssonius **1154,** Kanehira **1206, 1209,** Record **1837, 1843, 1851,** Record and Hess **1886.**

174. ERICACEAE

(FIG. 189 on p. 824; FIG. 190 on p. 826; FIG. 191 on p. 828)

SUMMARY

(i) GENERAL

A family of woody herbs, shrubs, and small trees, with leaves which are either leathery or of the familiar 'ericoid' type with recurved margins. The family is widely distributed, but species are especially numerous in China and South Africa. Species with adpressed leaves sometimes exhibit specializations of ecological rather than taxonomic interest. A great variety of **hairs** is to be found in the family. The **stomata,** in most instances, differ from those of the Vacciniaceae in being ranunculaceous, but exceptions occur. In the stem the **cork** arises in the pericycle internally to the thick-walled fibres; the **xylem** is in the form of a continuous cylinder including mostly uniseriate and occasional wider rays, as well as small vessels with simple perforations and/or scalariform plates. **Crystals** of calcium oxalate mostly clustered. Infection with **endotrophic mycorrhiza** is common. The formation of **root nodules** in association with mycorrhiza has been described in *Arbutus unedo* Linn. by Rivett (1944). Accounts of the occurrence of **ligno-tubers** (burls) at the base of the stem of *Arctostaphylos* have also been published by Jepson (1179, 1180) and by Wieslander and Schreiber (2390). Cant (340) has also drawn attention to the dilated stem bases in certain epiphytic Rhododendrons.

(ii) WOOD

Vessels typically very or extremely small and numerous, often exclusively solitary, occasionally with a tangential pattern, commonly semi-ring-porous, often with spiral thickening, perforation plates usually scalariform or scalariform and simple, intervascular pitting typically opposite or transitional, pits to parenchyma similar to the opposite pitting or occasionally elongated;

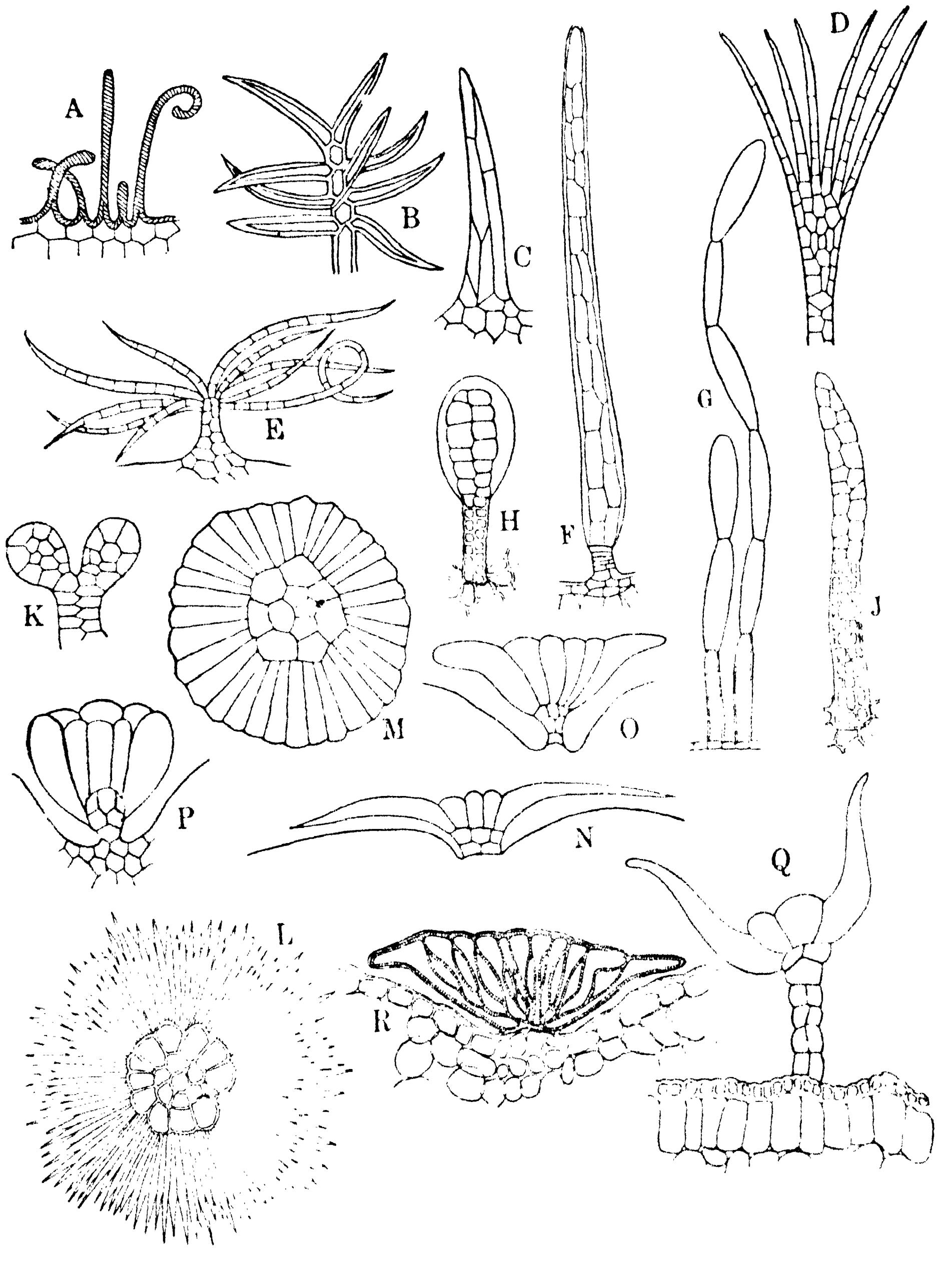


FIG. 191. *ERICACEAE*

A, Papillae of the lower side of the leaf of *Kalmia glauca* Ait. B, Abietiform hair, from *Rhododendron* sp. C, Shaggy hair of *R. molle* G. Don. (syn. *R. sinense* Sweet.). D, Broom-shaped shaggy hair of *R. lanatum* Hook. f. E, Stellate shaggy hair of *R. grande* Wight. F, External gland of *Xolisma ligustrina* Britt. (syn. *Lyonia ligustrina* DC.). G, External gland of *Cassiope fastigiata* Don. H, External gland of *Pieris floribunda* Benth. et Hook. J, Glandular hair of *Leucothoë catesbaei* Gray. K, Double glandular hair of *Rhododendron lanatum* Hook. fil. L, Peltate hair of *R. album* Bl. M, N, Peltate hair of *R. malayanum* Jack. O, Peltate hair of *R. dalhousiae* Hook. fil. P, Bud-shaped peltate hair of *R. pendulum* Hook. fil. Q, Cup-shaped peltate hair of *R. anthopogon* D. Don. R, Peltate gland of *R. ferrugineum* L.—A–E, K, M–P, after Breitfeld; F–J, after Niedenzu; L and Q, after O. Bachmann; R, after De Bary.

members of medium length. **Parenchyma** most commonly sparse or absent, moderately abundant and apotracheal (diffuse) in a few genera. **Rays** up to 3–10 cells wide or exclusively uniseriate, heterogeneous. **Fibres** typically with numerous distinctly bordered pits on all walls, septate in a few species, sometimes with spiral thickening, of medium length to very short.

LEAF

Mostly dorsiventral (Fig. 189 E), but sometimes isobilateral or centric. Species with thin leaves sometimes devoid of well-defined palisade tissue. Biological specializations include the familiar rolled leaves of *Erica* (Fig. 189 G and I) and the distinctive pocket-shaped leaves of *Cassiope redowskii* G. Don. According to Solereder, the adpressed leaves of *C. lycopodioides* D. Don. are provided with palisade cells on the lower and stomata on the upper surface. **Hairs** (Fig. 191) include many different kinds, roughly classified in the following categories. (i) Simple, non-glandular (Fig. 191 A–E), including branched stellate and shaggy types. (ii) Glandular, non-peltate of the types shown in Fig. 191 G–K. (iii) Peltate (Fig. 191 L–R). Variations of, and intermediates between, these types also occur. Peltate hairs present in lepidote but not in elepidote species of *Rhododendron*. For further details concerning the occurrence of different kinds of hair in individual species see Braun's (264) thesis and the other articles cited at the end of the description of the 'Leaf' (p. 830). **Cuticle** varying considerably in thickness, even within a genus, but nearly always more fully developed on the upper than on the lower surface except in species with leaves adpressed to the stem, e.g. in *Cassiope*. Cuticle commonly ridged or provided with a coating of wax. **Epidermis** often consisting of a single layer of cells, but frequently composed of several similar or dissimilar layers, especially in the Arbuteae and Rhodoreae. The epidermal cells vary considerably in shape and in the thickness of the walls; small and thick-walled in certain species of *Arctostaphylos*, *Kalmia*, and *Rhododendron*; cubical in many instances, but palisade-like in species of *Arbutus*, *Leucothoë*, *Pernettya*. Internal walls frequently mucilaginous, especially in the Ericeae and Rhodoreae. Lower epidermis papillose in species of *Erica*, *Kalmia*, and *Rhododendron*; upper epidermis sometimes papillose in *Erica*. **Stomata** generally occur only on the lower surface; confined to the grooves on the lower surface in species with rolled leaves; present on both surfaces in species of *Arctostaphylos*, *Cassiope*, *Epigaea*, *Pyrola*. Stomata, unlike those of the Vacciniaceae, generally ranunculaceous, but exceptions recorded, e.g. in species of *Diplycosia* and *Gaultheria*. Howell (1099) found that species of *Arctostaphylos* fall into 3 groups, based on differences in the distribution of stomata, as follows. (i) Stomata confined to the lower surface. (ii) Stomata equally numerous on both surfaces. (iii) Stomata more numerous on the lower than on the upper surface. Howell regards (i) as primitive and (ii) as more xerophytic and derived from (i). (iii), which consists almost wholly of Californian species, may have arisen as a result of crossing between species belonging to groups (i) and (ii). Howell says: 'Not only does varying disposition of stomata suggest fundamental lines of development in the genus, but it will probably prove to be a useful taxonomic criterion in classification.' **Mesophyll.** Walls of the palisade cells contractile in species of *Arbutus* and some of the Gaultherieae. Mesophyll including fibres or groups of sclerenchymatous elements situated at the leaf margin in species of *Diplycosia*, *Erica*, *Gaultheria*, *Leucothoë*, *Pernettya*. Vascular bundles of the **veins** mostly accompanied by mechanical tissue. Smaller veins embedded and sometimes vertically transcurrent. **Petiole,** in transverse sections through the distal end, exhibiting a single, openly crescentic, vascular strand in species of *Arctostaphylos* (Fig. 189 F), *Enkianthus* (pro parte) (Fig. 189 D), *Gaultheria* (Fig. 189 L), *Kalmia*, *Ledum*, *Leucothoë*, *Lyonia*, *Pieris*, *Zenobia*. Vascular strand similar, but rather more deeply crescentic in species of *Cassandra* and *Enkianthus* (pro parte). An approximately circular petiolar bundle was noted in *Rhododendron discolor* Franch (Fig. 189 J), and a somewhat similar bundle but flattened or slightly concave on the adaxial side was observed in *Arbutus* (Fig. 189 H). Copeland (465) refers to a single trough-shaped vascular bundle unaccompanied by fibres, and formed by the union of 2 vascular strands, in the petiole of species of *Chimaphila*, *Moneses*, *Pyrola*, and *Ramischia*. Nodes in the same species said to be unilacunar. Accessory strands in the cortex occasional, e.g. in *Arbutus* and *Rhododendron*. Cortical region of the petiole often tending to be composed of cells of very unequal size, thus giving a spongy appearance to transverse sections. This character noted particularly in species of *Gaultheria*, *Ledum*, *Pieris*, *Rhododendron*, *Zenobia*. **Secretory cells** with deeply staining, probably tanniniferous contents, very common in the ground tissue of the petiole. **Crystals** common in the petiolar ground tissues. Solitary types frequently observed in *Arbutus*, *Arctostaphylos*, *Leucothoë*, *Pieris*, and clusters in species of *Cassandra*, *Enkianthus*, *Gaultheria*, *Kalmia*, *Ledum*, *Leucothoë*, *Pieris*, *Rhododendron*. Solitary and clustered crystals generally present, and often abundant in the lamina as well, but none observed by Braun (264) in *Erica carnea* Linn. and *E. tetralix* Linn.

The following detailed accounts of various individual species and hybrids in the family, with special reference to hair structure, have been published: by Braun (264) for various genera and species; by Turrill and Boodle (2306) and Smith (2152) for British species of *Erica*;[1] by Kratzmann (1277) and Hanausek (881) for the structure and function of the peltate glands of *Rhododendron hirsutum* Linn.; by Lavier-George (1322) for *Rhododendron williamsonianum* Rehd. et Wils., *R. orbiculare* Decne, and a hybrid between these 2 species; for a hybrid between a lepidote and an elepidote Rhododendron by Waterson (2366). For further detailed particulars the articles cited under 'Ecological Anatomy' on p. 833 should be consulted.

---

[1] Recent investigations made by Miss E. M. Slatter at Kew have led to the discovery that some of the short hairs or papillae on the lower surface of the leaves of *Erica tetralix* Linn. and related species are more complex in structure than was realized by Smith. Thus the structures in the grooves on the lower surface of the leaves of both *E. tetralix* and *E. mackiana* Bab. (syn. *E. mackaii* Hook.), which Smith describes as 'simple hairs', in fact have an elaborate but loose reticulum of thickenings on their walls. The reticulum is denser at the apex than at the base of the papillae. Careful examination has shown that the thickenings appear to support or to be surrounded by a layer of a transparent substance resembling mucilage which covers the abaxial surface of the leaves except for the midribs. Apart from revealing the complex structure of the papillae, Miss Slatter's work has fully confirmed that, provided fresh or well-preserved material is used, *E. mackiana* and closely related species of *Erica* can be distinguished from one another by the microscopical features of the hairs, papillae, and structure of the epidermis (2-layered in *E. mackiana* and 1-layered in *E. tetralix*) which Smith used for diagnostic purposes. In dried herbarium specimens, however, the differences, especially in the structure of the epidermis, are by no means so easy to see, and erroneous conclusions could easily be drawn.

AXIS

STEM (Fig. 189 M–N)

Cork arising on the inside of the pericyclic sclerenchyma in species of *Andromeda*, *Arbutus*, *Arctostaphylos*, *Azalea*, *Calluna*, *Cassandra*, *Cassiope*, *Enkianthus*, *Epigaea*, *Erica*, *Gaultheria*, *Kalmia* (Fig. 189 M), *Leucothoë*, *Lyonia*, *Rhododendron*, *Zenobia*, and probably throughout the family. Phellogen not always well defined. Primary **cortex** generally devoid of collenchyma; seen to consist of a network of narrow, thick-walled, elongated, often secretory cells, with much larger, isodiametric, mostly colourless cells in the meshes in certain species of *Andromeda*, *Gaultheria*, *Kalmia*, *Ledum*, *Leucothoë*, *Lyonia*, *Pieris*. Stone cells believed to occur occasionally in the cortex of certain species. **Pericycle** including a narrow, continuous or somewhat interrupted ring of small, thick-walled fibres in some species of *Andromeda*, *Arbutus*, *Arctostaphylos*, *Cassandra*, *Erica* (pro parte), *Gaultheria*, *Kalmia*, *Ledum*, *Leucothoë*, *Lyonia*, *Pieris* (Fig. 189 N), *Rhododendron*, *Zenobia*. No well-defined layer of pericyclic sclerenchyma noted in species of *Calluna*, *Cassiope*, *Enkianthus*, *Erica* (pro parte). Stone cells observed in the pericycle of species of *Leucothoë* and *Lyonia*. Pericycle of *Pyrola*, according to Solereder, sometimes containing a ring of sclerenchyma with radial extensions between the vascular bundles. **Phloem** consisting of very small elements, but including some fibres in species of *Arbutus*, *Erica*, *Lyonia*, *Pieris*. **Xylem** wide in relation to the total diameter of the stem; forming a continuous cylinder traversed by exclusively uniseriate rays in most of the genera examined at Kew, but occasional wider rays noted in other genera and species (Fig. 189 N); including very small, frequently somewhat angular vessels with simple perforations and/or scalariform plates. Vessels sometimes with spiral striations. Secondary growth frequently very slow; 88 annual rings in a stem of *Rhododendron ferrugineum* Linn. 2·2 cm. in diameter and 44 rings in a stem of *Rhodothamnus chamaecistus* Reichenb. recorded by Kangiesser and Leiningen (1216). **Pith** frequently homogeneous, but heterogeneous in species of *Chimaphila* (Holm 1034), *Elliottia*, *Leucothoë*, *Lyonia*, *Oxydendrum*, *Pernettya*, *Pieris*, and probably other genera; the heterogeneous type exhibiting the same type of structure as that described above for the cortex. **Secretory cells** with deeply staining, probably tanniniferous contents, present in the unlignified tissues of all of the species examined at Kew. **Crystals** fairly frequent in the unlignified tissues of some species, but none observed in others; mostly clustered. Clusters noted in species of *Enkianthus*, *Gaultheria*, *Lyonia*, *Pieris*, *Rhododendron*. Solitary crystals much less common, some noted at Kew in the cortex of *Arbutus*, *Arctostaphylos*, *Leucothoë*, *Pieris*.

WOOD (Fig. 190 B, C, D, and G)

Vessels typically very small (less than 50 μ mean tangential diameter) and often extremely small (less than 25 μ), e.g. in some species of *Andromeda*, *Calluna*, *Erica*, and *Ledum*, moderately small (50–100 μ) in some species of *Arbutus*, *Arctostaphylos*, *Craibiodendron*, *Erica*, *Oxydendrum*, and *Philippia*, and medium-sized (100–200 μ) in *Ficalhoa*; exclusively solitary (apart from apparent pairs produced by overlapping ends) in some species of *Erica*, *Ficalhoa*, *Gaultheria*, *Kalmia*, *Oxydendrum*, *Philippia*, and *Xolisma*, occasionally with a tendency to a tangential pattern, e.g. in *Andromeda*, *Pernettya*, and *Rhododendron*; rarely less than 40 per sq. mm., e.g. in *Erica melanthera* L. and *Ficalhoa laurifolia* Hiern., and often more than 100; exceptionally numerous (up to 200 or more per sq. mm.) in some species of *Andromeda*, *Calluna*, *Ledum*, and *Rhododendron*; ring-porous or semi-ring-porous in some species of *Andromeda*, *Arbutus* (1851), *Arctostaphylos*, *Elliottia* (1864), *Ledum*, *Lyonia*, *Philippia*, *Rhododendron* (1206, 1851), and *Xolisma*; spiral thickening present in species of *Andromeda*, *Arbutus*, *Arctostaphylos*, *Calluna* (1851), *Daboecia* (2158), *Elliottia* (1868), *Gaultheria*, *Kalmia* (1851), *Oxydendrum* (1851), *Pernettya*, *Rhododendron*, and *Satyria* (1868) and reported (2158) in the end walls of *Menziesia ferruginea* Smith. Perforation plates exclusively scalariform in *Andromeda*, *Cassiope* (2158), *Craibiodendron*, *Ficalhoa*, *Gaultheria*, *Kalmia*, *Ledum*, *Loiseleuria* (2158), *Lyonia*, *Menziesia* (2158), *Pernettya*, *Phyllodoce* (2158), *Rhododendron*, and *Xolisma*; perforation plates simple and scalariform in some species of *Agauria*, *Arbutus*, *Arctostaphylos*, and *Calluna*; perforation plates exclusively simple, or with only rare scalariform plates in some species of *Arbutus*, *Arctostaphylos*, *Calluna* (2158), *Daboecia* (2158), *Erica*, *Oxydendrum*, and *Philippia*. Intervascular pitting typically opposite and rather small or transitional; scalariform in *Agauria*; pits to ray cells usually similar to the opposite pitting and small, but sometimes with many large, elongated pits. Occasionally with small deposits; tyloses observed only in *Oxydendrum*. Mean member length 0·4–0·8 mm. **Parenchyma** typically very sparse or absent; when present, often in contact with the vessels, possibly owing to the frequency of the vessels rather than to any tendency to be paratracheal. More abundant and diffuse in *Arbutus*, *Ficalhoa*, *Philippia*, and *Xolisma*. Sometimes with chambered crystals in *Arbutus andrachne* L. Strands varying from 2 cells, e.g. in *Philippia*, to 8 cells, e.g. in *Ficalhoa*. **Rays** usually of 2 distinct sizes where the larger rays are 4 or more cells wide; exclusively uniseriate in *Calluna*, *Ledum*, *Menziesia* (2158), and *Rhododendron* p.p. (2158), up to 3 cells wide in some species of *Andromeda*, *Arbutus*, *Kalmia*, *Oxydendrum*, and *Rhododendron*, 4–10 cells wide in the other genera and in some species of *Andromeda*, *Arbutus*, and *Rhododendron*; typically less than 1 mm. high, but higher in *Agauria*, *Ficalhoa*, and *Gaultheria*; uniseriate rays usually numerous and composed of high upright cells, but sometimes few, e.g. in *Erica cinerea* L. and *Oxydendrum*, or only a few cells high and consisting of square cells, e.g. in *Arbutus*; usually 10–15 rays per mm., rather fewer than 12 per mm. in some species of *Arbutus*, *Craibiodendron*, *Oxydendrum*, and *Pernettya*, and 20 or more per mm. in some species of *Calluna*, *Ledum*, and *Rhododendron*; heterogeneous (Kribs's Type II A or, less commonly, I), commonly with up to 4 marginal rows of upright cells in *Andromeda* p.p., *Arbutus*, *Arctostaphylos*, *Erica* p.p., *Kalmia*, *Oxydendrum*, and *Philippia*, and with more numerous marginal rows in the other genera; without procumbent cells in woods with wholly uniseriate rays; sheath cells present in many of the woods with rays up to 5 or more cells wide, e.g. in some species of *Agauria*, *Craibiodendron*, *Erica*, *Gaultheria*, *Pernettya*, and *Philippia*. Commonly containing gummy deposits; crystals not observed. **Fibres** typically with numerous bordered pits, the borders large and distinct. With a few septate fibres with simple pits mixed with the fibre-tracheids or with septate fibres predominating in some species of *Agauria*, *Arbutus*, *Arctostaphylos*, *Oxydendrum*, and *Vaccinium*. Fibre-tracheids with spiral thickening present in some species of *Arbutus*, *Arctostaphylos* (1851), and *Gaultheria*. Sometimes with very numerous bordered pits in cells adjacent to the vessels and suggestive of tracheids. Mean length 0·5–1·3 mm.

LIGNO-TUBERS

Ligno-tubers or burls at the stem base of certain species of *Arctostaphylos* have been described by Jepson (1179, 1180) and by Wieslander and Schreiber (2390). According to the last authors 'the exterior surface of a large, well developed burl is simply an aggregation of latent buds, which sprout as the result of injury by fire or other agencies'. Fires may affect the size and shape of the burl but are not responsible for its existence. Cant (340) has drawn attention to the dilated stem bases which occur in certain epiphytic species of *Rhododendron* belonging to the *Maddenii* section. As with the burls of *Arctostaphylos*, several shoots, in place of the normal solitary one, arise from the swellings. The swellings are formed by the excessive development of the xylem, including the medullary rays, as well as of the phloem and periderm. They are thought to serve for the storage of food. Similar tubers occur in *Adenostoma* (Rosaceae) and *Eriodictyon* (Hydrophyllaceae).

RHIZOME AND STOLON

Epidermis replaced by a thick-walled **hypoderm** in old rhizomes of *Gaultheria procumbens* Linn. **Cork** in the same species and in the stolons of *Epigaea repens* Linn. forming several layers on the inside of the thick-walled, pericyclic fibres. **Endodermis** well defined in the stolons of *E. repens*. **Pith** homogeneous, consisting of thin-walled, amyliferous cells in the rhizome of *Chimaphila umbellata* Nutt; heterogeneous, with starch confined to the smaller cells in the stolons of *E. repens*.

ROOT

Root system frequently including **endotrophic mycorrhiza,** but none seen by Holm (1023, 1034, 1052, 1061) in *Arctostaphylos uva-ursi* (L.) Spreng., *Chimaphila umbellata* Nutt., *Epigaea repens* Linn., and *Gaultheria procumbens* Linn. Exodermis very distinct in *Gaultheria procumbens*. Inner cortex containing a 'supporting tissue' abutting on the endodermis in *Chimaphila umbellata*, but no corresponding tissue seen by Holm (l.c.) in *Arctostaphylos uva-ursi* or *Epigaea repens*. Primary structure usually diarch in species of *Chimaphila*, *Moneses*, *Pyrola*, and *Ramischia* examined by Copeland (465) who, however, also noted triarch structure in *Moneses*. Cork not seen by Copeland. The formation of **root tubercles** in *Arbutus unedo* Linn. from arrested secondary and successive lateral branches is described by Rivett (1944). A mildly parasitic mycorrhizal fungus is said to stimulate the formation of the tubercles. According to Jones (1189) the root cap of *Calluna vulgaris* (L.) Hull. is unusually large.

ECOLOGICAL ANATOMY

Interest has been taken in certain members of the family on account of their ecological anatomy. Small differences in the leaf structure of *Rhodo-*

dendron catawbiense Michx. from different habitats have been described by Cain and Oliver Miller (327). In exposed situations the leaves are smaller, more curled and scurfy, chlorophyll is more abundant, and the petioles stouter and shorter. Internally the palisade cells are taller and more numerous, and the ratio of palisade to spongy tissue higher, whilst the laminar tissues in general as well as the cuticle are thicker. Abessadze (1) has described the anatomy of *Rhododendron caucasicum* Pall. from damp habitats. In this species the leaves are more xeromorphic on the upper than on the lower part of the stem. The epidermal scales of *Rhododendron minus* Michx. (syn. *R. punctatum* Andr.) were believed by Duncan (615) to serve for the absorption of water. The same author also found *R. minus* to be very plastic. Sifton (2098) observed an interesting combination of so-called xeromorphic characters with others ordinarily considered as characteristic of hydrophytes in *Ledum groenlandicum* Oedr. Thus, while the cuticle is thick and the palisade rather closely packed, a considerable part of the mesophyll is occupied by lysigenous air-spaces alternating with the small veins of the leaf. The ecological anatomy of *Arctostaphylos uva-ursi* (L.) Spreng. has been described by Starr (2188), that of *Cassiope tetragona* D. Don. by Rikli (1938), and that of *Gaultheria antipoda* Forst. by Betts (187). A comparison with the specific conductivity of stems of *Rhododendron ponticum* Linn. with that of *Ilex aquifolium* (Aquifoliaceae) has been made by Rivett (1943).

Taxonomic Notes

(i) From General Anatomy

It is generally accepted by taxonomists that the Ericaceae, Pyrolaceae, and Monotropaceae are closely related to one another, and some authorities such as Henderson (953) and Copeland (465) consider that the last two groups should be regarded as sub-families of the Ericaceae. The following remarks are quoted from Henderson's article.

> 'It will be seen that the supposed differences between the Ericaceae and Pyrolaceae are broken down except that the ovary is completely 5-celled in the Ericaceae and incompletely 5-celled in the Pyrolaceae. The only distinction that holds between the Pyrolaceae and the Monotropaceae is the absence of green colouring matter in the latter. In *Monotropa hypopitys* small grains in the epidermis of the scales probably represent degenerate chloroplasts. The Pyrolaceae and the Monotropaceae therefore differ from the Ericaceae only in their gradually increasing saprophytism and in those characters which go hand in hand with this, i.e. the loss of green colouring matter, the reduction from shrubs to herbs, the reduction of leaves to scales, the ovary from 5-celled with central placentae to almost completely 1-celled with parietal placentae, the increase in the number of seeds and the reduction in their size and in the number of cells in the endosperm and embryo. There is a gradual increase in the amount of hyphal investment in the roots of *Chimaphila* through *Pyrola* to *Monotropa*, the most saprophytic, correlated with a gradual decrease in the number of layers in the root cap. In the structure of the secondary axis, there is a gradual decrease in the amount of wood formed, from typical Ericaceae, with very woody stems through *Chimaphila*, which is as woody as some of the smaller Ericaceae, through *Pyrola* and *Moneses* which are less woody to the Monotropaceae, reaching the climax in *Monotropa* where the amount of wood is very limited. Correlated with this there is a gradual increase in the amount of phloem. There is a gradual reduction in the size and structure of the leaves from

evergreen leathery in Ericaceae, *Chimaphila* and some of the Pyrolas, to less leathery in *Pyrola chlorantha* and *P. minor* to evergreen leaves but with deciduous structure in *Moneses*, scales which are brownish (*Pterospora*), brownish-yellow or yellow (*Monotropa hypopitys*), red (*Sarcodes*), brownish-white (*Pleuricospora*) to white (*Monotropa uniflora*). Stomata are very numerous in the leaves of some of the Ericaceae, become less numerous in the Pyrolaceae, very few in the scales of *Monotropa* and *Pterospora*, and absent entirely in those of *Sarcodes*. All of these changes are correlated with increasing saprophytism.'

(ii) FROM WOOD STRUCTURE

The woods of this family and those of the Vacciniaceae are of a generally unspecialized type, although the vessel members are not particularly long and though some features, such as spiral thickening and the division of the fibrous elements into 2 types, are evidence of some degree of specialization.

Record (1837) in a study of the Ericales draws the following conclusions.

> 'From the studies so far made of the woods of this order (i.e. Clethraceae, Epacridaceae, Ericaceae, and Vacciniaceae) it appears that they comprise a fairly homogeneous group without sharp division into families along the lines proposed by taxonomists, except probably in the case of Epacridaceae. Generic and some specific differences often are pronounced. Relationship of the Ericales to the Theaceae seems to be strongly indicated.'

ECONOMIC USES

Many members of the family, particularly the Rhododendrons, Azaleas, and Heaths, are cultivated for ornamental purposes. *Calluna vulgaris* (L.) Hull. was at one time extensively used in the New Forest (in Britain) and elsewhere for the manufacture of besoms. The fruits of *Gaultheria shallon* Pursh. are edible. Labrador Tea, which consists of the dried leaves of *Ledum groenlandicum* Oedr., is characterized by air cavities in the lamina.

Various species have been, and some still are, used in medicine. Thus the leaves of *Arctostaphylos uva-ursi* (L.) Spreng. possess diuretic and astringent properties and exhibit the following microscopical characters. Epidermis composed of polygonal cells; ranunculaceous stomata confined to the lower surface; mesophyll with palisade tissue towards both surfaces except near the midrib; vascular bundles surrounded by collenchyma, the latter including solitary and prismatic crystals; small droplets of oil in most of the cells. For further details see Holm (1052). According to Holm (1061) the leaves of *Epigaea repens* Linn. have been substituted for those of *Arctostaphylos uva-ursi*. The leaves of the substitute are characterized by a wrinkled cuticle; stomata on both surfaces; isobilateral mesophyll. *Chimaphila umbellata* Nutt., which also possesses diuretic properties, is characterized by an isobilateral mesophyll; ranunculaceous stomata confined to the lower surface; epidermal cells with moderately thick, sinuous, anticlinal walls. For further details see Holm (1034). Oil of Wintergreen, formerly used in medicine, is derived from the leaves of *Gaultheria procumbens* Linn. According to Holm (1023) the leaf of this species is characterized by an isobilateral mesophyll; mostly rubiaceous stomata; vascular bundles accompanied by a few layers of fibres.

The only wood of any importance is the root-wood of *Erica arborea* Linn., from which brier pipes are made. Record and Hess (1886) state that some species of *Arctostaphylos* and *Befaria* are used locally for turnery and small cabinet work.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Andromeda,* Arbutus,* Arctostaphylos,* Azalea, Calluna,* Cassandra,* Cassiope,* Chimaphila, Diplycosia, Enkianthus,* Epigaea, Erica,* Gaultheria,* Kalmia,* Ledum,* Leucothoë,* Lyonia,* Moneses, Oxydendrum, Pernettya, Pieris,* Pyrola, Ramischia, Rhododendron,* Rhodothamnus, Zenobia.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Agauria, Andromeda, Arbutus, Arctostaphylos, (Befaria), Calluna, Craibiodendron, (Daboecia), (Elliottia), Erica, Ficalhoa, Gaultheria, Kalmia, Ledum, (Loiseleuria), Lyonia, (Menziesia), Oxydendrum, Pernettya, Philippia, (Phyllodoce), Rhododendron, (Satyria), Xolisma.

LITERATURE

(i) *On General Anatomy*

Abessadze **1**, Betts **187**, Braun **264**, Cain and Oliver Miller **327**, Cant **340**, Copeland **465**, Duncan **615**, Hanausek **881**, Henderson **953**, Holm **1023**, **1034**, **1052**, **1061**, Howell **1099**, Jepson **1179**, **1180**, Jones, W. N. **1189**, Kangiesser and Leiningen **1216**, Kratzmann **1277**, Lavier-George **1322**, Petersen **1704**, Rikli **1938**, Rivett **1943**, **1944**, Sifton **2098**, Smith **2152**, Starr **2188**, Turrill and Boodle **2306**, Waterston **2366**, Wieslander and Schreiber **2390**.

(ii) *On Wood Structure*

den Berger **182**, Betts **188**, **189**, Brown, H. P. and Panshin **289**, Cormio **475**, Forsaith **691**, Greguss **2522**, Howard **1088**, Jones **1191**, Kanehira **1206**, **1209**, Pearson and Brown **1679**, Record **1783**, **1837**, **1843**, **1851**, **1864**, **1867**, **1868**, **1869**, **1875**, Record and Hess **1886**, Thompson **2254**, Yamabayashi **2478**.

175. CLETHRACEAE

(FIG. 192 on p. 838; FIG. 194 on p. 848)

SUMMARY

(i) GENERAL

A family of shrubs and small trees belonging to the single genus *Clethra* which occurs in Madeira, south-eastern United States, central and tropical South America, and parts of tropical Asia (Hutchinson 1113). Interesting anatomical features of the young stem include the short, multicellular, stellate **hairs** which occur in at least some of the species: the continuous cylindrical **xylem** including vessels with scalariform perforation plates; the common occurrence of **secretory cells** and clustered **crystals** in the unlignified tissues.

(ii) WOOD

Vessels exclusively solitary, perforation plates scalariform with numerous bars, intervascular pitting opposite and small, members moderately to very long. **Parenchyma** diffuse. **Rays** up to 5 or 6 cells wide, markedly heterogeneous. **Fibres** with distinctly bordered pits, of medium length to very long.

LEAF

Multicellular, woolly **hairs** recorded by Solereder in *Clethra arborea* Ait. Lamina examined in *C. arborea* and '*C. wilsoni*'. Strongly dorsiventral in both species, the **mesophyll** including about 2 layers of tall palisade cells. Upper **epidermis** composed of cells with dark-yellowish contents in *C. arborea*, but epidermal cells with similar contents much less numerous in '*C. wilsoni*'. **Stomata** confined to the lower surface; mostly rubiaceous, but a few cruciferous and ranunculaceous types noted in both species. Vascular bundles of the smaller **veins** sheathed and sometimes vertically transcurrent by moderately thick-walled cells, some of them filled with yellowish-brown contents, the latter being more common in '*C. wilsoni*' than in *C. arborea*. **Midrib** with an almost closed cylindrical bundle, flattened or slightly concave towards the adaxial side. **Petiole,** in transverse sections through the distal end, exhibiting a crescent-shaped vascular strand with strongly incurved ends in specimens of *C. alnifolia* Linn., *C. arborea* (almost closed in this species) (Fig. 194 C), *C. tomentosa* Lam., and '*C. wilsoni*' cultivated and examined at Kew. Accessory strands observed in the wings in *C. alnifolia* and '*C. wilsoni*'. **Secretory cells** with unidentified, amorphous contents noted in the 'cortical' region of the petiole in the same species. Secretory cells with yellowish brown amorphous contents also abundant in the phloem of the midrib in *C. arborea* and '*C. wilsoni*'. **Crystals** abundant, mostly clustered; especially large druses present in idioblasts in the palisade tissue of both species; a few solitary and sphaerocrystals also noted in the tissues surrounding the vascular strand of the midrib.

AXIS

YOUNG STEM (Fig. 194 G)

Short, multicellular, stellate **hairs** noted in *C. alnifolia* Linn., *C. tomentosa* Lam., and '*C. wilsoni*'. **Cork** arising in the pericyclic region (Fig. 194 G); consisting of thin-walled cells in *C. alnifolia*, '*C. wilsoni*', and probably other species. **Pericycle** devoid of sclerenchyma in the few species examined. **Phloem** and **xylem** in the form of continuous cylinders, traversed by narrow rays. A few thick-walled, pitted, sclerotic cells noted in the phloem of *C. arborea* but not in the other species. Vessels somewhat angular, usually up to about 40 μ in radial diameter, but the dimensions varying somewhat in different species; lateral pitting bordered; perforation plates very oblique and scalariform with numerous very fine bars. Wood fibres consisting of fairly thick-walled elements with bordered pits. **Pith** often moderately wide, very heterogeneous; peripheral portion consisting of thick-walled cells in *C. arborea*. **Secretory cells,** with unidentified amorphous contents, usually present in unlignified tissues, sometimes especially numerous in the phloem, e.g. in *C. arborea*. Clustered **crystals** generally occur in the cortex and pith; solitary types recorded by Solereder in the phloem of *C. arborea*.

WOOD (Fig. 192 F–G)

Vessels moderately small (50–100 μ mean tangential diameter); exclusively solitary, apart from apparent tangential pairs due to overlapping ends; about 17 per sq. mm.; sometimes with fine spiral thickening in the tips of the members. Perforation plates scalariform, with 20–50 fine bars. Intervascular pitting opposite and small; pits to parenchyma similar. Williams (2426) notes tyloses in *C. lanata* Mart. et Gal. Mean member length 0·8–1·5 mm. **Parenchyma** apotracheal, as isolated cells and short uniseriate bands scattered among the fibres. Strands of 4–12 cells. **Rays** of 2 sizes, the larger up to 5 or 6 cells wide; multiseriate rays often more than 1 mm. high in *C. sumatrana* J. J. S.; uniseriates few in *C. lanata* (2426) to numerous in *C. sumatrana* and composed of high upright cells; about 12 rays per mm.; markedly heterogeneous (Kribs's Type I), commonly with 4–10 marginal rows of square to upright cells and sometimes with a tendency to sheath cells. **Fibres** with numerous, distinctly bordered pits on both radial and tangential walls. Walls moderately thick. Mean length 0·9–2·4 mm.

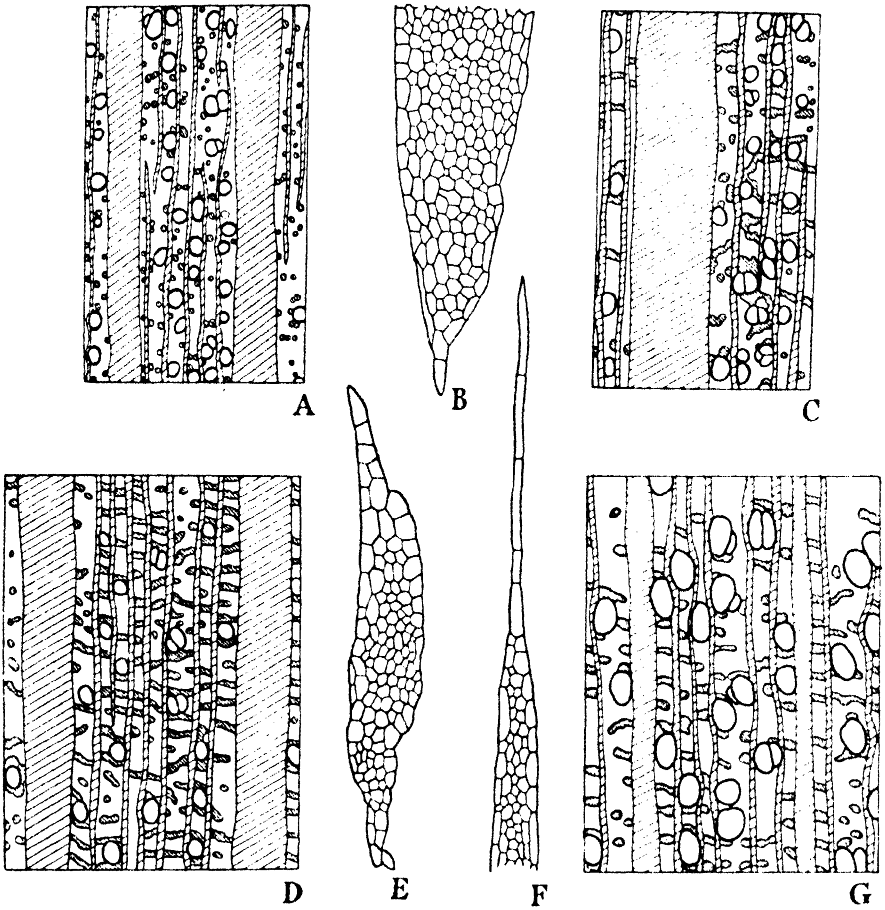


FIG. 192. *EPACRIDACEAE*, A–E; *CLETHRACEAE*, F, G

A, *Leucopogon richei* R.Br. B, *Dracophyllum latifolium* A. Cunn. C, *Monotoca elliptica* R.Br. D, *Trochocarpa laurina* R.Br. E, *T. laurina* R.Br. F, *Clethra sumatrana* J. J. Smith. G, *C. sumatrana* J. J. Smith.

ROOT

Ridge-like thickenings to the walls of the cells situated outside the endodermis recorded by Solereder in *C. arborea* Ait.

TAXONOMIC NOTES

Clethra has many anatomical features in common with the Ericaceae, in which family it was included in the Bentham and Hooker system. Record (1837) made a comparison of the wood anatomy of *Clethra* and *Schizocardia* and concluded that there is not a close relationship between these 2 genera, and that *Clethra* is more primitive than *Schizocardia*.

ECONOMIC USES

Several species of *Clethra* are commonly cultivated in Britain for ornamental purposes. The Lily of the Valley Tree of Madeira is *C. arborea* Ait.

GENUS DESCRIBED

FOR GENERAL ANATOMY AND WOOD STRUCTURE

Clethra.*

* Represented in the Kew slide collection.

LITERATURE

(i) *On General Anatomy*

Hutchinson **1113**.

(ii) *On Wood Structure*

den Berger **182**, Kanehira **1209**, Lechner **1328**, Record **1837**, **1843**, **1851**, **1867**, **1868**, Record and Hess **1886**, Williams **2426**.

176. MONOTROPACEAE

SUMMARY

Typical chlorophyll is almost or completely absent from the members of this north temperate herbaceous family. In consequence they are saprophytic. They do not exhibit any other unusual anatomical feature except that **stomata** are infrequent in the much reduced leaves. The roots are provided with **mycorrhiza.** The lateral roots of *Pterospora* and *Sarcodes* arise exogenously.

LEAF

Mesophyll homogeneous, consisting of isodiametric cells. Non-glandular, unicellular **hairs** present, but stalked glands and glandular shaggy hairs also occur. **Epidermis** always composed of cells with straight anticlinal walls. **Stomata** rare, present according to Henderson (953) in *Monotropa* and *Pterospora*, but absent from *Sarcodes*.

AXIS

STEM

Stomata recorded by Solereder in *Pterospora*. The vascular system, according to Solereder, consists of closed **vascular bundles** arranged in a ring;

bundles embedded in the parenchymatous ground tissue in species of *Sarcodes* and *Schweinitzia*, surrounded by a relatively broad ring of slightly prosenchymatous elements with slit-like pits in the cells in species of *Hypopitys, Monotropa, Pterospora.* The tracheal elements, according to Solereder, are doubtfully to be regarded as true vessels, although provided with pits or annular or spiral thickenings. Copeland (464), on the other hand, describes 2 kinds of vascular structure as follows. (i) Stem including a vascular cylinder with a sheath of fibres in *Allotropa, Pterospora, Sarcodes.* (ii) Stem including a vascular cylinder or vascular bundles without a sheath of fibres in *Hypopitys, Monotropa, Monotropastrum, Monotropsis, Pityopus, Wirtgenia.* **Tanniniferous elements** with wide lumina recorded in the ground tissue and vascular system of *Monotropa.* Further information concerning the secondary thickening of the stem and root of *Monotropa hypopitys* Linn. has been published by Queva (1766).

TAXONOMIC NOTES

The Monotropaceae are related to the Ericaceae, but exhibit various structural reductions which are correlated with their saprophytic mode of life. Henderson's (953) views on this subject are quoted more fully under Ericaceae (p. 834). Copeland (464) also considers that the group should be regarded as a sub-family of the Ericaceae.

GENERA DESCRIBED

Allotropa, Hypopitys, Monotropa, Monotropastrum, Monotropsis, Pityopus, Pterospora, Sarcodes, Schweinitzia, Wirtgenia.

LITERATURE

On General Anatomy

Copeland **464,** Henderson **953,** Queva **1766.**

177. EPACRIDACEAE

(FIG. 192 on p. 838; FIG. 193 on p. 842; FIG. 194 on p. 848)

SUMMARY

(i) GENERAL

Woody herbs, shrubs, or small trees, often with an ericoid appearance. The family occurs mainly in parts of Australia and New Zealand. The leaves show various biological specializations. They are sometimes grooved, and, in these, the stomata are confined to the grooves. The pores of the ranunculaceous **stomata** are generally parallel to the long axis of the leaves, although exceptions are known to occur. The cells of the **epidermis** are also elongated in the same direction as the long axis of the leaf in certain species. The simple, scanty **hairs** provide a distinguishing character from the Ericaceae. The number of **vascular bundles** and their position in the mesophyll, as well as the arrangement of the sclerenchyma around them, are all characters of taxonomic value. The vascular bundles of the leaf usually lie approximately parallel to one another and are deeply embedded in the mesophyll, but in some species they are close within the lower epidermis. The **petiole** is seldom developed, but in those species in which one occurs, it exhibits 3, 5, or 6 almost parallel, separate, vascular bundles supported externally by well-developed masses of fibres. In the **stem** it is interesting to note that the **cork** arises internally to the pericyclic fibres and that a typical phellogen is not always developed. Other features of the stem include the narrow **cortex;** the occurrence of fibres in the secondary phloem; the **xylem** occupying most of the thickness of the stem and including small vessels and very numerous, narrow medullary rays; the small **pith** which becomes sclerified at an early stage, and, in some species, is heterogeneous. A detailed account of the anatomy of numerous species of Epacridaceae has been published in the form of a comprehensive thesis by Étienne (663). Considerable use of this work has been made in compiling the present description.

(ii) WOOD

Vessels very to extremely small and solitary, sometimes with spiral thickening, perforations partly or wholly simple or plates exclusively scalariform and sometimes irregularly reticulate, intervascular pitting scalariform, opposite or alternate, members of medium length. **Parenchyma** apotracheal, diffuse or in fine bands, sometimes very sparse. **Rays** commonly up to 10 or more cells wide and heterogeneous. **Fibres** with distinctly bordered pits; moderately to very short.

LEAF

Lamina somewhat variable, but most frequently dorsiventral (Fig. 194 H), e.g. in *Cyathodes* (Betts 189) and *Pentachondra* (Betts 188). Palisade tissue recorded by Solereder on both sides of the small leaves of *Andersonia* and *Dracophyllum*, but the whole mesophyll consists of isodiametric cells in other species of *Dracophyllum*. Palisade tissue usually well developed, sometimes constituting half the thickness of the mesophyll; consisting of a variable number of layers of cells. Palisade cells sometimes provided with contractile walls. Walls of the cells of the spongy mesophyll considerably thickened where bordering on the intercellular spaces. **Hairs** infrequent; different from those of the Ericaceae in being very uniform, mostly unicellular, but varying in length and in the thickness of the cell walls. **Cuticle** always very thick except in a few species from damp localities, e.g. *Epacris paludosa* R.Br., *Leucopogon australis* R.Br., *Lysinema lasiantha* R.Br. Thick cuticle sometimes coated with wax. The **epidermis,** according to Étienne (663), consists of the following types of cells in certain species of the genera mentioned, but the differences are only of specific and not of generic diagnostic value. (i) Epidermal cells on the upper surface appreciably taller than wider, and larger than those of the lower surface, in species of *Acrotriche*, *Brachyloma*, *Conostephium*, *Cyathodes*, *Cyathopsis*, *Dracophyllum*, *Leucopogon*, *Lissanthe*, *Monotoca*, *Richea*, and in *Pentachondra pumila* R.Br. according to Betts (188). (ii) Epidermal cells on both surfaces sub-rectangular in species of *Coleanthera*, *Lebetanthus*, *Leucopogon*, *Pentachondra*, *Styphelia*, but those of the upper somewhat larger than those of the lower surface. (iii) Epidermal cells on both surfaces equal in size in species of *Archeria*, *Melichrus*, *Oligarrhena*. (iv) Cells of the lower larger than those of the upper epidermis in species of *Cosmelia*, *Dracophyllum*, *Lysinema*, *Sprengelia*. Epidermal cells frequently elongated parallel with the longitudinal axis of the leaf; anticlinal walls, according to Solereder, nearly always sinuous except in certain species of *Coleanthera*, *Dracophyllum*, *Epacris*, *Leucopogon*, *Styphelia*. Lateral walls of the epidermal cells said to be provided with thickenings projecting into the interior of the cells, e.g. in *Pentachondra pumila* R.Br. and *Styphelia elegans* Sond. Epidermis consisting of several layers of cells in at least certain parts of the leaf in *Cyathodes acerosa* R.Br., *Dracophyllum traversii* Hook., *Lissanthe strigosa* R.Br. Lower epidermis papillose in *Cyathodes acerosa* R.Br. according to Betts (189). A **hypoderm** of lignified cells recorded by Betts (188) towards the adaxial surface of the leaf base in *Dracophyllum urvilleanum* A. Rich. **Stomata** small, most frequently confined to the abaxial surface and in particular to the grooves in species in which these occur; present, according to Solereder, on both surfaces in *Andersonia* and *Dracophyllum*, particularly in species with leaves strongly adpressed to the stem, even confined to the adaxial surface in a few species of *Leucopogon*. Pores of the stomata usually parallel to the long axis of the leaf, except, according to Solereder, in *Lysinema*, and described as obliquely orientated in *Conostephium pendulum* Benth. by Étienne (663).

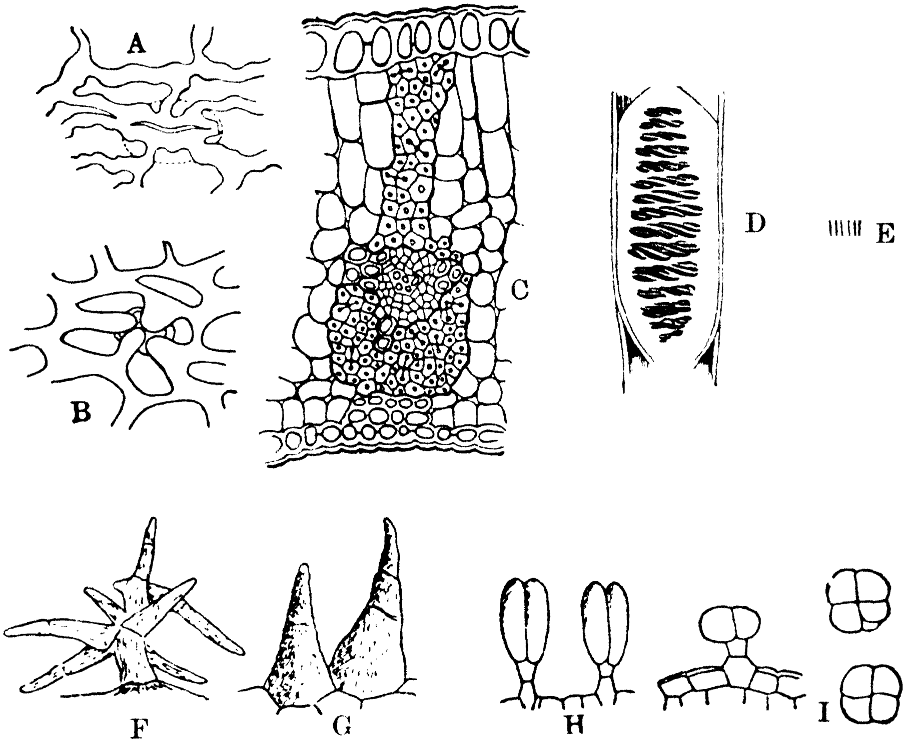


FIG. 193. *EPACRIDACEAE*, A–D; *PRIMULACEAE*, E–I

A, B, Surface-view of a stoma of *Archeria eriocarpa* Hook. fil. (A) and *Sprengelia ponceletia* F. Muell. (B) with the accompanying neighbouring cells, seen from the inside. C, Section of a vein of the leaf of *Richea dracophylla* R.Br.—After Simon. D, Modified scalariform perforation plate of *Epacris heteronema* Labill.—By Solereder. E–I, Hairs: E, *Androsace arachnoidea* Schott.; F, *A. multiscapa* Duby; G, *A. elongata* Linn.; H, *Cyclamen persicum* Mill.; I, *Lysimachia nummularia* Linn.—After Kamienski.

Guard cells frequently sunken and accompanied by outgrowths (Fig. 193 B) from the surrounding walls into the cavities above the stomata, e.g. in species of *Andersonia*, *Lysinema*, *Needhamia*, *Oligarrhena*, and *Sprengelia*. Stomata in a few species described as opening to the exterior through slit-shaped apertures, e.g. in *Archeria* (Fig. 193 A).

Mesophyll in species of *Andersonia* said by Solereder to include sclerenchymatous idioblasts extending to the epidermis. All of the **vascular bundles** in a single leaf generally about equal in size, but the median one tends to be the largest in leaves with 3–5 bundles. The number of bundles in each leaf, according to Étienne (l.c.), varies according to the species as follows. Sometimes 3, e.g. in *Needhamia*; more frequently 5, e.g. in *Cyathodes oxycedrus* R.Br., *Lebetanthus americanus* Endl., *Oligarrhena micrantha* R.Br.; numerous in most species, especially those included in *Dracophyllum* and *Richea* (Fig. 194 H). Vascular bundles contiguous to the lower epidermis in the Styphelieae (except *Needhamia*) and amongst the Epacreae in *Andersonia*, *Archeria*, *Dracophyllum*, *Lysinema*, *Richea*; embedded in the centre of the mesophyll in *Needhamia* amongst the Styphelieae, and in *Cosmelia*, *Epacris*, *Lebetanthus*, *Prionotes*, *Sprengelia* in the Epacreae. The nature of the tissue surrounding the vascular bundles is also of diagnostic value as follows. (i) Vascular bundles surrounded by a sheath of sclerenchyma in species of *Andersonia*, *Archeria*, *Cosmelia*, *Dracophyllum* (exceptionally), *Epacris*, *Lebetanthus*, *Needhamia*, *Oligarrhena*, *Prionotes*, *Sprengelia*, *Trochocarpa*. (ii) Accompanied on the abaxial side by well-developed sclerenchyma in nearly all of the Styphelieae and in *Sphenotoma*. (iii) At least some of the bundles vertically transcurrent by means of sclerenchyma so as to form I-shaped girders in *Dracophyllum*, *Leucopogon* (in the thick veins), *Richea* (Figs. 193 C and 194 H). Mechanical elements surrounding the vascular bundles provided with thick walls, narrow lumina, and sometimes with bordered pits. Sclerenchymatous elements supporting the leaf margin also recorded by Betts (188) in *Dracophyllum*.

Petiole (Fig. 194 B) developed in a few species only, the remainder being provided with sessile leaves sometimes with sheathing bases, exhibiting several isolated vascular strands embedded in parenchyma when viewed in transverse sections. Three to 6 bundles recorded by Étienne (l.c.) in different species as follows. Three bundles in *Acrotriche cordata* R.Br., *Archeria traversii* Hook. f., *Coleanthera myrtoides* Stch., *Epacris microphylla* R.Br., *E. virgata* Hook. f., *Leucopogon melaleucoides* Cun., *Trochocarpa gunnii* Benth.; 5 bundles in *Conostephium preissii* Sond., *Cyathopsis floribunda* B. et G., *Leucopogon richei* R.Br., *Pentachondra involucrata* R.Br.; 6 in *Cyathodes glauca* Labill. and *Leucopogon australis* R.Br. Vascular bundles of the petiole generally supported by a massive development of sclerenchyma in the pericycle. Dormer (603) recently observed typical unilacunar nodes and narrow leaf bases in species of *Acrotriche*, *Brachyloma*, *Epacris*, *Lebetanthus*, *Lysinema*, *Needhamia*, *Oligarrhena*, *Pentachondra*, *Styphelia*, *Trochocarpa*, and suspects that *Archeria*, *Conostephium*, *Prionotes*, and *Woollsia* exhibit a similar structure. A single foliar trace also occurs in species of *Cosmelia* and *Sprengelia* with sheathing and overlapping leaf bases, the single vascular strand dividing to form 2 branches 'which run almost horizontally round the base of the sheath', and give off smaller strands which constitute the parallel venation of the leaf.

Leaves of *Cosmelia* and *Sprengelia* become detached from the stem in the region of the pericycle, the entire cortex of the internode below remaining attached to the base of the leaf. In a few species of *Dracophyllum* and *Richea*, with overlapping sheathing leaf bases, Dormer observed a median and several lateral leaf traces. These often pass out so abruptly and at such different levels that all of the traces could seldom be seen in a single section. The nodal anatomy of *Dracophyllum* and *Richea* thus differs from that of *Cosmelia* and *Sprengelia*, the leaves of the last 2 of these genera also separating from the stem in a normal manner and leaving typical scars.

Crystals often abundant in the leaf; solitary types in the endodermis frequently accompany the vascular bundles; also recorded in the epidermis of species with a well-developed sclerenchymatous sheath around the vascular bundles. Clustered crystals also occur. According to Étienne (l.c.) very large crystals are sometimes present in the mesophyll, e.g. in *Conostephium pendulum* Benth. **Secretory cells** containing tannin common; e.g. recorded by various authors in *Cyathodes*, *Dracophyllum*, *Pentachondra*.

AXIS

STEM (Fig. 194 E)

Primary **cortex** generally narrow, consisting of rounded, thin-walled, somewhat spongy parenchyma; described as moderately wide in *Pentachondra pumila* R.Br. by Betts (189). **Cork** arising on the inside of the pericyclic sclerenchyma (Fig. 194 E); not always arising from a distinct phellogen, according to Solereder, an observation confirmed in *Richea* by Curtis (517). Three types of cork formation recognized by Étienne (663) according to the size of the plant when mature. (i) Cork consisting of a single layer of suberized cells in very small plants, e.g. *Needhamia pumila* R.Br. and *Oligarrhena micrantha* R.Br. (ii) Cork consisting of several layers of cells arising from a single phellogen in plants of average size for the family. This type noted particularly in herbarium specimens consisting of relatively immature stems. (iii) Cork arising from a first phellogen succeeded by others originating internally to the phloem fibres in relatively large species, e.g. *Epacris virgata* Hook., *Leucopogon albicans* Br. et Gr., *Lysinema pungens* R.Br. Cork cells, especially when first formed, rectangular and much taller than broad in species of *Brachyloma*, *Coleanthera*, *Cosmelia*, *Dracophyllum*, *Epacris*, *Leucopogon*, *Lysinema*, *Melichrus*, *Monotoca*, *Sprengelia*, *Styphelia*, *Trochocarpa*; consisting of small, thick-walled cells in *Cyathodes acerosa* R.Br. according to Betts (189). Cork cells throughout the family characterized by a thin, suberized, and lignified middle lamella and a very thick internal cellulose lamella, the latter becoming considerably thicker and occupying a large part of the cavity of the cork cell when sufficiently mature.

An **endodermis** with suberized walls recorded by Étienne (l.c.) only in *Needhamia pumila* and *Oligarrhena micrantha*, but recognizable in sufficiently young stems of numerous other species by the presence of abundant starch grains and sometimes of calcium oxalate crystals. **Pericycle** provided with a composite and continuous or occasionally somewhat interrupted ring of sclerenchyma, about 2-4 cells wide; usually ephemeral owing to the activity of the sub-adjacent phellogen. Secondary **phloem** often including fibres, either solitary or in groups, and, according to Solereder, provided with mixed bordered and simple pits. The following particulars concerning the distribution of phloem fibres have been recorded by Étienne. (i) Phloem fibres solitary in various species of *Epacris* and in *Conostephium pendulum* Benth. (ii) In small groups in *Epacris microphylla* R.Br. and *Lissanthe ciliata* R.Br. (iii) In larger, irregular groups in various species of *Cyathopsis* and *Dracophyllum* as well as in *Andersonia caerulea* R.Br. and *Epacris virgata* Hook. (iv) Arranged in large plates in various species of *Cyathodes* and *Lysinema pungens* R.Br. and forming a more or less complete ring in *Acrotriche aggregata* R.Br., *Leucopogon albicans* Br. et Gr., and *L. thymifolius* Lindl.

Xylem in the form of a continuous cylinder, traversed by narrow rays and constituting most of the thickness of the stem. Vessels in '*Epacris miniata*' examined at Kew, up to about 30 μ in radial diameter, mostly arranged in radial rows or oblique clusters, and some of them provided with scalariform perforation plates; in *Leucopogon lanceolata* R.Br., also from Kew, seldom exceeding 20 μ in diameter and mostly solitary. Similar wood structure, but with no reference to the nature of the perforations, recorded by Betts (188) in *Dracophyllum urvilleanum* A. Rich. and in *Richea* by Curtis (517), but, according to Betts, a few broad, unlignified rays occur in *D. rosmarinifolium* R.Br. Vessels described by Curtis (l.c.) as having bordered pits or scalariform pitting in *Richea*. Reticulate perforation plates in *Epacris* recorded by Thompson (2254). Modified scalariform perforation plates recorded in *Epacris* (Fig. 193 D).

The following particulars concerning the wood structure of 31 species of Epacridaceae which he examined are quoted from Étienne's thesis. Vessels mostly solitary, more rarely in groups of 2–3; radial diameter 10–35 (average 22) μ and tangential diameter 7–30 (average 19) μ. Primary vessels with spiral or annular thickening; those of the secondary xylem irregularly scalariform, reticulate or pitted, sometimes with scalariform perforation plates. Wood fibres constituting the bulk of the xylem; consisting of elements with large or small lumina in different species. Rays very numerous and narrow, mostly uniseriate, but sometimes biseriate, e.g. in species of *Acrotriche*.

Pith usually very small, but sometimes rather larger, e.g. in species of *Dracophyllum* and *Richea*; heterogeneous in species of *Cosmelia*, *Dracophyllum*, and *Richea*; including thickened, pitted cells in *Cyathodes acerosa* R.Br. (Betts 189) and *Pentachondra pumila* R.Br. (Betts 188); consisting of small, thickened cells interspersed with large intercellular spaces in *Dracophyllum* (Betts 188). **Crystals** of calcium oxalate, according to Étienne (l.c.), less frequent in the stem than in the leaf; solitary prisms, often present in longitudinal rows of cells, occur in the phloem; less common and mostly in the form of druses in the smaller cells of the pith. Solereder records crystalline conglomerates in the pith of *Dracophyllum*, and solitary crystals in the pith of certain other genera, as well as crystalline masses of calcium oxalate in *Coleanthera myrtoides* Stsch. Groups of 2–16 relatively large cells with thin cellulose walls, containing large solitary crystals, described from the pith and cortex of *Richea* by Curtis (517). **Secretory cells** with unidentified but probably tanniniferous contents noted at Kew in the unlignified tissues of '*Epacris miniata*'; similar cells recorded in *Cyathodes acerosa* R.Br. (Betts 189), *Dracophyllum*, *Pentachondra* (Betts 188).

WOOD (Figs. 192 A–E and 193 D)

Vessels typically less than 50 μ in mean tangential diameter and sometimes extremely small (less than 25 μ), e.g. in *Dracophyllum* and *Richea*; in the small stems investigated by Étienne (663) the mean diameter ranged from 7 to 35 μ; exclusively solitary, apart from apparent tangential pairs due to overlapping ends, and without pattern in all the material examined of *Cyathodes*, *Dracophyllum*, *Monotoca*, *Richea*, and *Trochocarpa*, and in *Leucopogon richei* R.Br., but, according to Lüders (as quoted by Solereder), distinct radial rows are more common than a scattered arrangement; oblique lines observed in *Leucopogon fasciculatus* A. Rich. and tangential lines reported by Garratt (744) in *Dracophyllum latifolium* A. Cunn.; 30–300 per sq. mm., most numerous (more than 200 per sq. mm.) in some species of *Dracophyllum* and *Richea*. Spiral thickening observed or reported (2158) in some species of *Acrotriche*, *Cyathodes*, *Epacris*, and *Lysinema*. Perforation plates wholly simple to exclusively scalariform and sometimes irregularly reticulate; Lüders lists the following: simple only in some species of *Andersonia*, *Archeria*, *Asteroloma*, *Brachyloma*, *Coleanthera*, *Conostephium*, *Leucopogon*, *Lissanthe*, *Melichrus*, *Needhamia*, and *Styphelia*; simple with a few scalariform plates with few bars in species of *Acrotriche*, *Andersonia*, *Conostephium*, *Cyathodes*, *Leucopogon*, *Lissanthe*, *Lysinema*, *Melichrus*, *Oligarrhena*, and *Styphelia*; mostly or wholly scalariform and with fewer than 20 bars in species of *Cyathopsis*, *Epacris*, *Monotoca*, *Sphenotoma*, and *Trochocarpa*; wholly scalariform and with 20 or more bars in species of *Cosmelia*, *Dracophyllum*, *Lebetanthus*, *Pentachondra*, *Prionotes*, *Richea*, *Sprengelia*, and *Woollsia*. Normal scalariform plates in *Epacris lanuginosa* Labill. and *E. heteronema* Labill. are accompanied by peculiar modified types, as illustrated in Fig. 193 D. Intervascular pitting tending to be small and alternate in species with simple perforations and opposite to scalariform in the others; sometimes with fine spiral striations in *Dracophyllum* (744); pits to ray and wood parenchyma similar to the intervascular pitting. Horizontal resin plates occasionally present in *Dracophyllum* (744). Mean member length 0·4–0·5 mm. **Parenchyma** apotracheal, scattered among the fibres or forming numerous fine bands; sparse in some species, e.g. in *Dracophyllum latifolium* A. Cunn., *D. longifolium* R.Br., and *Richea pandanifolia* Hk. f. Chambered crystals reported by Lüders in *Acrotriche*, *Leucopogon*, and *Monotoca*. Strands usually of 2 or 4 cells. **Rays** typically of 2 distinct sizes except in very small stems, the larger up to 4–20 cells wide, commonly 10 or more cells wide in some species of *Dracophyllum*, *Monotoca*, and *Trochocarpa*. In the small stems examined by Étienne (663) the rays were all narrow (1, occasionally 2–3, cells wide) and low for their width. The large rays high, sometimes up to 4 mm.; uniseriate rays very numerous and composed of upright cells; multiseriate rays sometimes very few in *Richea pandanifolia*; aggregate rays present in *Dracophyllum longifolium* R.Br.; 10–27, mostly 16–20, rays per mm.; heterogeneous (Kribs's Type II A), the large rays sometimes with up to about 8 marginal rows of square or upright cells and occasionally composed mainly of square to upright cells with few truly procumbent cells; sheath cells usually present. Often with abundant gum-like contents. **Fibres** typically with distinctly bordered pits and thick walls; Solereder records spiral thickening in *Epacris paludosa* and *E. microphylla* R.Br. and quotes Baccarini as stating that occasional septate fibres with simple pits occur in *Lysinema pungens* R.Br., *Monotoca scoparia* R.Br., *Sprengelia incornata* Sm., and species of *Epacris*. Mean length 0·5–1·0 mm. Étienne (663) comments on the occurrence in many species of alternating layers of (*a*) numerous, relatively large vessels together with fibres with large lumina, and (*b*) few or narrow vessels and very thick-walled fibres with much reduced lumina.

TAXONOMIC NOTES

The anatomy of the Epacridaceae has points in common with that of the Ericaceae. Étienne (663) found Bentham and Hooker's classification of the Epacridaceae to be more logical than that of Drude (610), basing this opinion mainly on exomorphic characters. At the same time, Bentham and Hooker's arrangement of the family was found to conform with conclusions based on anatomical considerations. Étienne discovered no anatomical features to favour the fusion of *Melichrus* with *Styphelia*, the differences in the leaf structure of these 2 genera being particularly noteworthy. Dormer (603) considers that the nodal anatomy (see under 'Petiole') of *Dracophyllum* and *Richea* indicates that these genera are rather distinct from the rest of the family.

ECONOMIC USES

Although the family includes ornamental species which are commonly cultivated under glass in Britain, it includes no products of economic importance.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Acrotriche, Andersonia, Archeria, Brachyloma, Coleanthera, Conostephium, Cosmelia, Cyathodes, Cyathopsis, Dracophyllum, Epacris,* Lebetanthus, Leucopogon,* Lissanthe, Lysinema, Melichrus, Monotoca, Needhamia, Oligarrhena, Pentachondra, Prionotes, Richea,* Sphenotoma, Sprengelia, Styphelia, Trochocarpa.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

(Acrotriche), (Andersonia), (Asteroloma), (Brachyloma), (Coleanthera), Cyathodes, Dracophyllum, (Epacris), Leucopogon, (Lissanthe), (Lysinema), Monotoca, (Prionotes), Richea, (Sprengelia), Trochocarpa, (Woollsia).

LITERATURE

(i) *On General Anatomy*

Betts **187**, **188**, **189**, Curtis **517**, Dormer **603**, Drude **610**, Étienne **663**, Thompson **2254**.

(ii) *On Wood Structure*

Curtis **517**, Dadswell and Record **533**, Étienne **663**, Garratt **744**, Record **1800**, **1851**, Thompson **2254**.

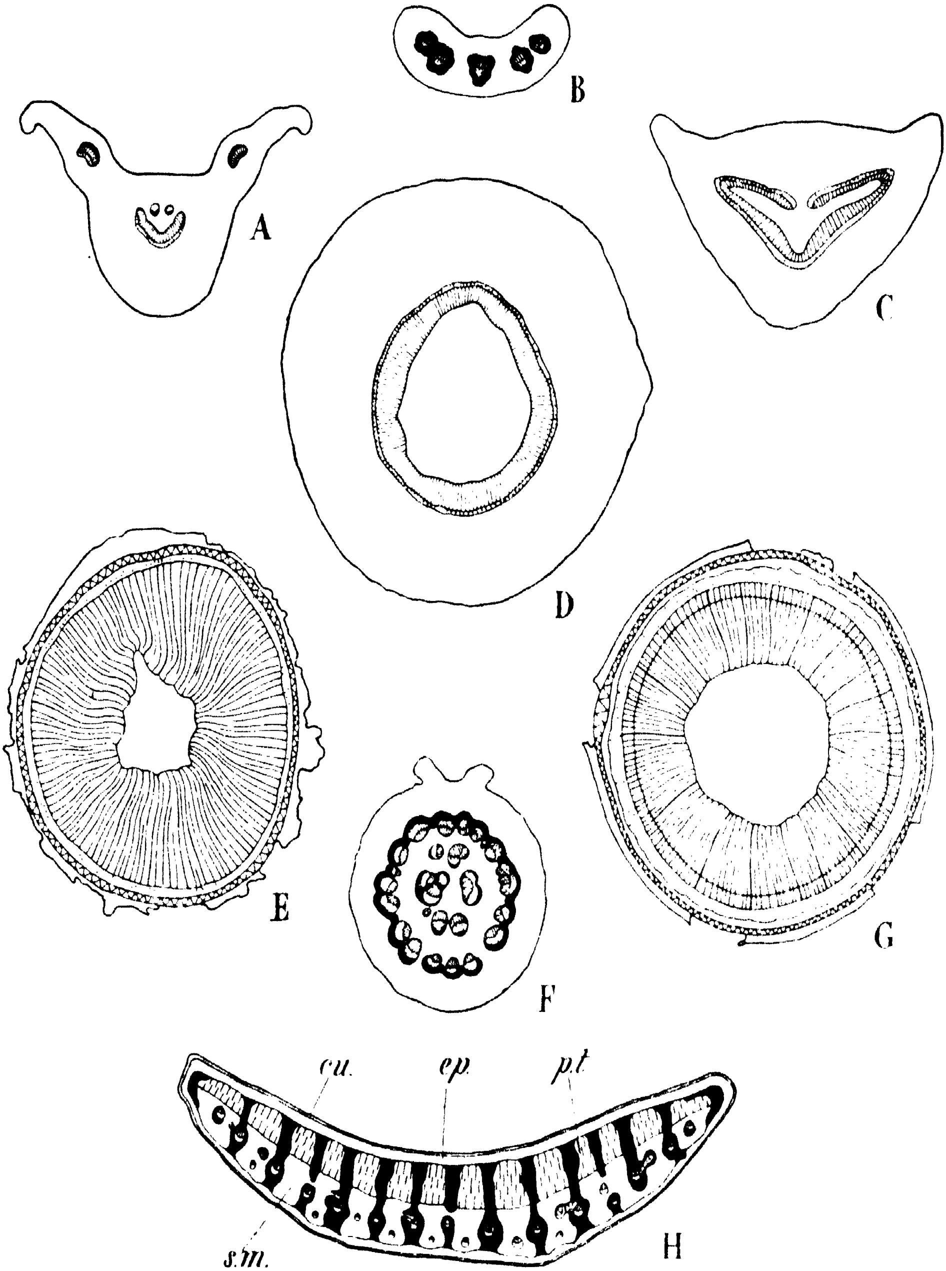


Fig. 194. *DIAPENSIACEAE*, A, D, and F; *EPACRIDACEAE*, B, E, and H; *CLETHRACEAE*, C and G

A, *Shortia galacifolia* Torr. et Gray. Petiole × 19. B, *Epacris* sp. Petiole × 31. C, *Clethra arborea* Ait. Petiole × 18. D, *Galax aphylla* Linn. Stem × 19. E, *Epacris* sp. Stem × 19. F, *Galax aphylla* Linn. Petiole × 19. G, *Clethra alnifolia* Linn. Stem × 18. H, *Richea scoparia* Hook. f. Leaf (T.S.) × 30.

cu. Cuticle. *ep.* Epidermis. *p.t.* Palisade tissue. *s.m.* Spongy mesophyll.

178. DIAPENSIACEAE

(Fig. 194 on p. 848)

SUMMARY

A mainly north temperate family consisting mostly of small, heath-like shrubs, which differ from the Ericaceae in the absence of glandular **hairs.** *Diapensia lapponica* Linn., of which the anatomy has been described by Petersen (1705), is a cushion plant with ecto- and endotrophic **mycorrhiza.**

LEAF

Usually dorsiventral, but sometimes homogeneous and consisting of isodiametric cells in *Galax* and *Shortia.* **Hairs** infrequent or absent except, according to Diels (582A) in *Pyxidanthera.* **Epidermis** composed of cells with sinuous, often unevenly thickened, anticlinal walls; the upper epidermal cells of *Shortia uniflora* Maxim described by Diels (582A) as having inwardly directed projections from the cell wall. Lower epidermis papillose in *Berneuxia* (papillae thickened) including *B. thibetica* Decaisne (syn. *Shortia thibetica* Franch.). Chlorophyll recorded in the epidermis of *Diapensia* and *Galax.* **Stomata,** according to Solereder, present on both surfaces in species of *Diapensia*, *Galax*, *Pyxidanthera*, *Schizocodon*, *Shortia*; confined to the lower surface in *Berneuxia* (Diels 582A), *Diapensia lapponica* Linn. (Petersen 1705) (absent from the sheathing base in this species), and in *Galax aphylla* Linn. examined at Kew; more numerous on the upper than on the lower surface in *Diapensia himalaica* Hook. (Diels 582A); mostly ranunculaceous, but at least a proportion of them seen to be cruciferous in *Galax aphylla* and *Shortia galacifolia* Torr. et Gray. Guard cells of *Galax aphylla* almost circular in surface view. **Mesophyll** including 3 layers of palisade cells in *Berneuxia*, 2–3 layers in *Diapensia lapponica*, and a single layer in *Shortia uniflora.* Spongy mesophyll of *Diapensia lapponica* containing a proportion of thick-walled cells. Vascular bundles of the **veins** not accompanied by sclerenchyma in *Shortia uniflora.* **Petiole** of *Galax aphylla*, in transverse sections through the distal end, exhibiting a circle of widely spaced bundles enclosing some medullary strands (Fig. 194 F); that of *Shortia galacifolia* provided with a median, crescentic bundle, accompanied by 2 additional strands between the ends on the adaxial side and by 2 more strands in the wings (Fig. 194 A). **Crystals** mostly clustered, but solitary ones recorded by Solereder in *Galax.* Varying quantities of **tannin** and **oily substances** recorded in *Diapensia lapponica* (Petersen 1705).

AXIS

STEM (Fig. 194 D)

Inner part of the **cortex** collenchymatous in *Diapensia lapponica* Linn. (Petersen 1705). **Cork,** according to Solereder, superficial in *Galax*, but arising in the pericycle in *Diapensia* and *Pyxidanthera*; only slightly developed in *Diapensia lapponica* (Petersen 1705); composed of cells with U-shaped thickenings in *Pyxidanthera.* **Xylem** in *Galax aphylla* Linn. examined at Kew (Fig. 194 D) consisting of a narrow, continuous cylinder with no well-defined rays, and including a few, somewhat angular vessels up to about 20 μ

in radial diameter and provided with simple perforations. Ground tissue of the xylem in the same species consisting of fibres with abundant bordered pits. Vessels rarely with scalariform perforation plates in *Diapensia lapponica*, according to Solereder. All elements of the xylem of *D. lapponica*, apart from the vessels, described by Petersen (1705) as exhibiting a folded appearance, more apparent in glycerine than in Canada balsam mounts. Growth rings in the same species not very well defined. **Pith** frequently heterogeneous, consisting of thin- and thick-walled cells. Cluster **crystals** observed at Kew in the cortex of *Galax aphylla*, and abundant **secretory cells** with unidentified but probably tanniniferous contents in the cortex and medullary rays of the same species. Oil said by Petersen (1705) to be abundant in the tissues of *Diapensia lapponica* during winter and spring.

Root

Young roots provided with **mycorrhiza** in *Diapensia lapponica* Linn. **Cork** poorly developed and **phloem** described by Petersen (1705) as showing collenchymatous thickening in the same species.

Taxonomic Notes

Diels (582A) considers that the affinities of the Diapensiaceae are closer to those of the Saxifragaceae than of the Ericaceae. He pointed out that the Diapensiaceae differ from the Ericaceae in the lack of subsidiary cells around the stomata, and, except for *Pyxidanthera*, in the scantiness of the hairy covering. These differences do not seem very significant, however, for although those between the Vacciniaceae and Ericaceae are just as great, it is generally accepted that these 2 families are closely related. It seems reasonable, on anatomical grounds, to regard the Diapensiaceae as coming within the compass of the Ericales, but the subject needs further investigation. Some of the genera of Diapensiaceae are not very easily separated from one another. For particulars of the Sino-Himalayan species of *Shortia* and *Berneuxia* see the article by Li (1372).

Genera Described

Berneuxia, Diapensia, Galax,* Pyxidanthera, Schizocodon, Shortia.*

* Represented in the Kew slide collection.

Literature

On General Anatomy

Diels **582A**, Grevel **819**, Li Hui Lin **1372**, Petersen **1705**.

179. LENNOACEAE

Summary

The 3 genera *Ammobroma*, *Lennoa*, and *Pholisma* constitute this small family of herbs, confined to Mexico and California. Being devoid of chlorophyll and having reduced leaves they live as parasites, notably on the roots of *Clematis*, *Eriodictyon*, and *Prosopis*. The base of the plants often lies buried in sand up to the level of the inflorescence. The family has not received much attention from anatomists since Suessenguth's (2220) important article on the structure and biology of *Lennoa* was published. In *Lennoa*, the stem, which is 5–7 cm. long and 1–2 cm. thick, is connected to the root system of the host plant by haustoria which arise from the tip of the root of the parasite.

LEAF

Reduced to scales; those of *Lennoa* arranged spirally. **Hairs** each having a single stalk cell and a 1- or occasionally 4-celled head recorded in *Lennoa* by Suessenguth (2220). **Stomata** usually numerous and present on both surfaces, but said to be confined to the lower side in species of *Lennoa*. Transverse sections of the scale leaves of *Lennoa* described as showing about 7 **vascular bundles.**

AXIS

STEM

Epidermis bearing stalked, glandular **hairs** and perforated by **stomata. Phloem** said by Solereder to contain sieve tubes, but no typical sieve plates observed in *Lennoa* by Suessenguth (2220). **Vascular system** in *Ammobroma* and *Lennoa* consisting of a ring of large, isolated bundles accompanied by smaller cortical leaf traces. Bundles embedded in a uniform, parenchymatous ground tissue, consisting of rounded or polygonal cells containing starch. Transverse sections of *Ammobroma* just below the floral receptacle exhibit numerous scattered vascular bundles, but the ground tissue is composed of collenchyma with a small intercellular space in the middle of each thickening. **Xylem** of *Ammobroma* said by Solereder to be composed of pitted and reticulate vessels with rather wide, almost circular lumina; perforations simple, circular. Xylem of *Lennoa* described by Suessenguth (2220) as including tracheids but no vessels.

ROOT

The following information concerning the root system of *Lennoa* has been recorded by Suessenguth (2220). Very few roots fail to become connected with the root system of the host plant. Transverse sections through roots of the first order exhibit an outer parenchymatous portion including a little starch; no distinct line of demarcation between the stele and the extrafascicular tissue; a circle of 8–16 collateral vascular bundles with active fascicular cambium, the protoxylem groups of adjacent bundles sometimes tending to be united so as to appear as a ring in transverse sections; a pith free from starch and including 1 to several small groups of unlignified cells with narrow lumina. Lateral roots, with 3–4 ill-defined xylem groups, arise exogenously from those of the first order.

GENERA DESCRIBED

Ammobroma, Lennoa, Pholisma.

LITERATURE

On General Anatomy
Suessenguth **2220.**

180. PLUMBAGINACEAE

(FIG. 195 on p. 852; FIG. 196 on p. 854)

SUMMARY

(i) GENERAL

Herbs, shrubs, or climbers, including a number of plants such as species of *Armeria* and *Limonium* which are familiar in temperate salt marshes and maritime districts. The most characteristic feature of the family is the occurrence on both leaf and stem of characteristic epidermal **glands** which secrete mucilage and/or calcium salts. These secretory structures are sometimes referred to as chalk glands, on account of the calcareous matter which is exuded from them and covers the leaf surface in some species. The structure of the glands has not always been interpreted in exactly the same way by all authors, Ruhland (1967) in particular having taken exception to the

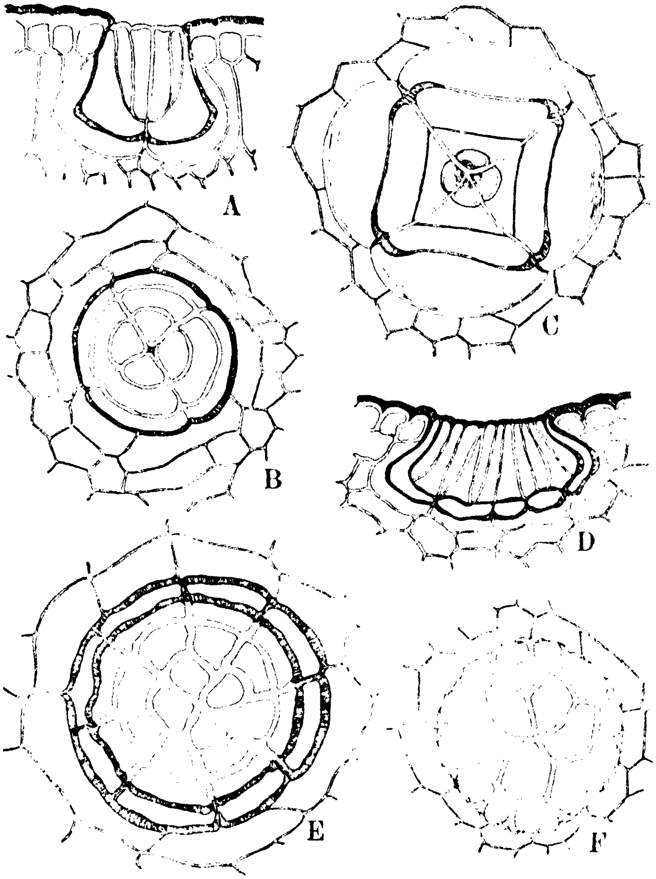


FIG. 195. *PLUMBAGINACEAE*

A–C, Ordinary glands from the surface of the leaf of *Aegialitis annulata* R.Br. A, Transverse section; B, Surface-view from outside; C, from within. D–F, Mucilage-gland on the leaf-sheath of *Aegialitis annulata* R.Br. D, Transverse section; E, Surface-view from outside; F, from inside.

description of them given by Solereder. The differences of opinion refer to details rather than to the fundamental structure of the glands. Stalked glands and glandular shaggy hairs also occur. **Secretory cells** filled with plumbaginin are also to be found in the stem and root of many species. **Cortical** and **medullary bundles** are fairly common in the axis. *Acantholimon* and *Aegialitis* exhibit **anomalous secondary thickening.**

(ii) WOOD (*Plumbago capensis* Thunb.)

Vessels very small, sometimes with a radial pattern, perforations simple, intervascular pitting very small, alternate, pits to ray cells similar; members extremely short. **Parenchyma** paratracheal, scanty. **Rays** up to 3 cells wide, cells almost all square or upright. **Fibres** with simple pits, often septate, extremely short. **Included phloem** of the concentric type present in some genera.

LEAF

Mesophyll differing in structure in species with flattened and acicular leaves respectively; homogeneous, composed of rounded cells in *Plumbago europaea* Linn.; not clearly differentiated into palisade and spongy portions in *Limonium elatum* Fisch. and according to Sayeedud-Din (2009) *Plumbago zeylanica* Linn.; dorsiventral in *P. larpentae* Lindl. and centric in species of *Acantholimon* (Fig. 196 A), *Armeria* (Fig. 196 C), *Limoniastrum*, and *Limonium*; cauline leaves centric, but radical leaves dorsiventral in *Limonium sinuatum* Linn. Mesophyll normally isobilateral in *Limonium bineruosum* (G. E. Sm.) C. E. Salmon, but showing dorsiventral structure in this species, according to de Fraine (556), when raised from seed in cultivated ground. **Hairs** mostly simple, unicellular, but long-stalked glandular shaggy hairs sometimes present as well, particularly on the floral organs, e.g. on the calyx of *Plumbago capensis* Thunb. and *P. zeylanica*. **Secretory glands** (Fig. 195) of 2 kinds occur in the family. (i) Chalk glands, also known as Mettenius or Licopoli glands, universally present on or depressed below the surface of the leaf lamina and stem; sometimes surrounded by warts composed of enlarged epidermal cells or by simple hairs. Individual glands of this kind composed of 4 or 8 palisade-like epidermal cells,* surrounded by 1 or 2 layers, each composed of 4 'subsidiary' cells (Fig. 195 A–C). The cell walls between the secretory cells of the gland and the surrounding subsidiary cells are cuticularized. Secretory organs of this type are generally described as chalk glands because they commonly exude deposits of calcium salts as well as water, the former sometimes becoming secondarily spread over the leaf or stem surface by the action of rain, &c. The quantity of calcium salts secreted depends on the nature of the soil; no calcareous matter is secreted by British species of *Limonium* investigated by de Fraine (556). The somewhat similar glands of *Aegialitis* (Fig. 195 D–F), composed of a larger number of secretory cells, serve to secrete mucilage. (ii) Raised mucilage glands also present in various members of the family; those in the leaf axils and on the upper surface of the leaf base of *Limonium bellidifolium* (Gouan) Dum. and *L. binervosum* described by de Fraine (556) as each having a head borne on a base composed of a few stout-walled cells, and protected by cuticle. **Epidermis** often composed of cells with wide lumina; anticlinal walls straight or sinuous. **Stomata** generally present on both surfaces, but, in *Limonium binervosum* and *L. bellidifolium*, the relative proportion on either side varies in relation to habitat; mostly irregularly orientated, but, in narrow-leaved species of *Acantholimon* and *Limonium*, having their pores parallel to the longitudinal axis; rubiaceous in species of *Acantholimon* and *Armeria* with grass-like leaves; cruciferous or ranunculaceous in certain other species; cruciferous stomata recorded in *Plumbago zeylanica* by Sayeedud-Din (2009) and by de Fraine (556) in *Limonium*

---

* According to some authors there are 4, and to others 8, of these cells.

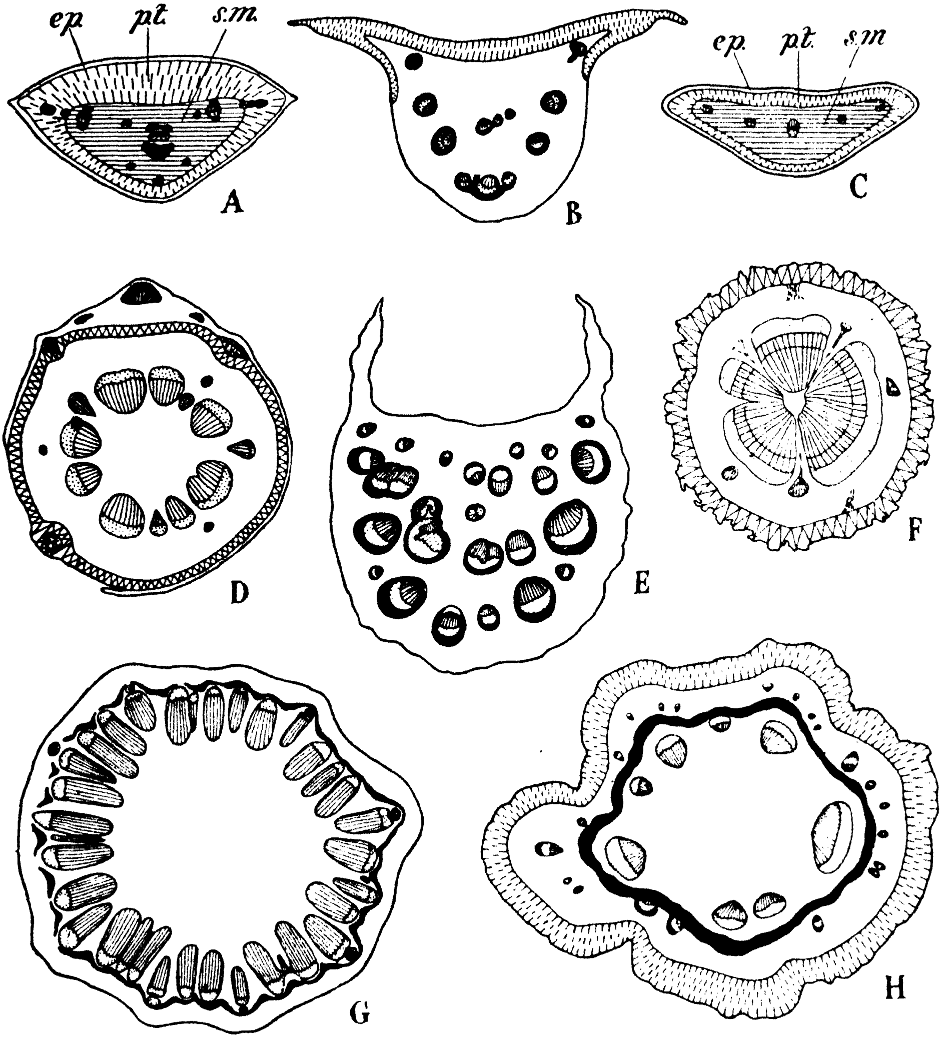


FIG. 196. *PLUMBAGINACEAE*

A, *Acantholimon glumaceum* Boiss. Leaf (T.S.) × 22. B, *Limonium vulgare* Mill. Petiole × 15. C, *Armeria vulgaris* Willd. Leaf (T.S.) × 27. D, *Acantholimon glumaceum* Boiss. Stem × 24. E, *Limonium* sp. Petiole × 19. F, *Armeria vulgaris* Willd. Stem × 9. G, *Plumbago europaea* Linn. Stem × 19. H, *Limonium vulgare Mill.* Stem × 19.

ep. Epidermis. *p.t.* Palisade tissue. *s.m.* Spongy mesophyll.

bellidifolium and *L. binervosum*, although frequently ranunculaceous in the last of these species. Branched sclerenchymatous idioblasts recorded in the palisade tissue of a few species of *Aegialitis*, *Limoniastrum*, *Limonium* (present in *L. binervosum* but not in *L. bellidifolium* (de Fraine 556)). Vascular bundles of the **veins** vertically transcurrent by slightly sclerosed palisade cells with slit-like pits in species of *Aegialitis* and *Limonium*; not accompanied by sclerenchyma in other species such as *Plumbago larpentae* Lindl. Vascular bundles numerous, the median strand being surrounded by sclerenchyma in *Limonium binervosum*; similar, but with small caps of fibres above and below the main veins, in *L. bellidifolium*. **Petiole,** in transverse sections through the distal end, exhibiting scattered bundles in *Ceratostigma griffithii* C. B. Clarke, and species of *Limonium* (Fig. 196 B and E) in material examined at Kew. Scattered vascular bundles in the petiole also recorded by Sayeedud-Din (2009) in *Plumbago zeylanica*, and 3 main and numerous smaller bundles in *Limonium binervosum* by de Fraine (556). A considerable diversity of petiole structure recorded by Solereder as occurring in different members of the family. **Crystals** of calcium oxalate very rare; small clusters recorded in *Plumbago zeylanica* by Sayeedud-Din (2009). Cells filled with a **granular secretion,** probably consisting of plumbaginin, recorded in the same species by the same author. **Tannin** or allied substances abundant, especially in the sub-epidermis and around the mid-vein in *Limonium binervosum.*

ECOLOGICAL ANATOMY

In *Limonium binervosum* (G. E. Sm.) C. E. Salmon modifications of structure in relation to habitat have been recorded by de Fraine (556), who particularly noted variations in the thickness and degree of striation of the cuticle; in the thickness of the walls of the epidermal cells; in the frequency of stomata on both surfaces of the leaf; in the quantity and distribution of sclerenchyma in the petiole. Other features observed were the normally isobilateral replaced by dorsiventral mesophyll in plants raised from seed in cultivated ground; the numerous vascular bundles, the median one encircled by sclerenchyma; the numerous sclereids in the mesophyll; the abundant tanniniferous deposits, particularly in the sub-epidermis and around the mid-vein.

AXIS

STEM (Fig. 196 D, F, G, and H)

Flowering stem in some species of *Plumbago* and *Limonium* provided with wings, a persistent epidermis perforated by numerous stomata (the latter frequently depressed), and a peripheral band of chlorenchyma (sometimes palisade-like) in *Limonium*. Surface of the stem in *Ceratostigma* and *Vogelia* frequently provided with cellular prominences enclosing sclerenchymatous elements. Outer part of the **cortex** collenchymatous in *Plumbago europaea* Linn. **Cork** arising in the sub-epidermis in species of *Aegialitis* and *Limoniastrum*; originating about 3 or 4 cell layers deep in the cortex in *Acantholimon glumaceum* Boiss and *Armeria* sp., especially well developed and having the outer part furrowed in the last of these species. **Pericycle** containing a ring or strands of fibres; a continuous or only slightly interrupted circle of thick-walled, narrow, strongly lignified fibres noted at Kew in *Ceratostigma griffithii* C. B. Clarke, *Plumbago europaea* Linn., and in *Limonium vulgare* Mill.

Sclerenchyma also stated by Solereder to occur in the cortex and pith of *Limonium*. **Vascular system,** in transverse sections, appearing as individually distinct bundles in all of the few species examined at Kew, the bundles being relatively widely spaced in *Acantholimon* (Fig. 196 D), *Ceratostigma, Limonium* (Fig. 196 H), and *Plumbago* (Fig. 196 G). Xylem dissected by a few broad rays with enlarged distal ends in *Armeria vulgaris* Willd. (Fig. 196 F). Vessels, in the species examined at Kew, mostly with reticulate pitting and always with simple perforations. Ground tissue of the xylem of herbaceous species described by Solereder as composed of unlignified elements or of fibres, the latter, when present, provided with simple pits. **Cortical bundles** recorded by Solereder in species of *Aegialitis, Armeria, Goniolimon, Limoniastrum, Limonium,* and noted at Kew in *Plumbago europaea* and *Limonium vulgare*. **Medullary bundles** occur in species of *Acantholimon* (collateral and inversely orientated) and *Limonium* (mostly centric with central phloem). **Secretory cells** with unidentified but probably tanniniferous contents abundant in unlignified tissues of the few species of *Acantholimon, Armeria, Ceratostigma, Limonium,* and *Plumbago* examined at Kew. **Crystals** absent from material examined at Kew.

SUBTERRANEAN STEM

The following facts concerning the short subterranean stems of *Limonium bellidifolium* (Gouan) Dum. and *L. binervosum* (G. E. Sm.) C. E. Salmon have been taken from de Fraine's (556) paper. *L. binervosum*. **Cork** fairly broad. **Cortex** composed of small-celled, rounded parenchyma including numerous groups of sclereids having strongly thickened walls perforated by branched pits. **Endodermis** not distinguishable. **Pericycle** including a strand of sclerenchyma opposite each vascular bundle. **Xylem** traversed by broad rays; vessels consisting of elements with simple pits, except for spiral thickenings in the protoxylem. **Pith** large, composed of thin-walled parenchyma including numerous groups of sclereids. **Tannin** abundant in the cork and cortex. Stems of the same species from different habitats vary in the proportion of mechanical tissue present, and in the size of the vessels. Stem of *Limonium bellidifolium* essentially similar to that of *L. binervosum* except for the broader cork, the spongy cortex with only one series of groups of sclereids and other minor differences.

WOOD (*Plumbago capensis* Thunb.)

Vessels very small (about 50 μ mean tangential diameter), solitary and in clusters and short radial multiples, with a distinct radial pattern in the inner rings; about 50 per sq. mm.; perforations simple; intervascular pitting very small, alternate; pits to parenchyma similar. Mean member length about 0·15 mm. **Parenchyma** paratracheal, limited to a few cells about the vessels. Strands usually of 2 cells. **Rays** up to 3 cells wide with numerous uniseriates, the cells of both very irregular in size and shape in tangential sections and almost all square or upright in radial sections; less than 1 mm. high; about 5 rays per mm. **Fibres** with simple pits, some fibres septate, walls moderately thin, mean length about 0·3 mm. **Included phloem** of the concentric type reported by Record (1851) in *Acantholimon, Aegialitis,* and *Limoniastrum*.

ANOMALOUS STRUCTURE, see last paragraph above.

ROOT

Structure described in some detail, but mainly from an ecological standpoint, for *Limonium bellidifolium* (Gouan) Dum. (a salt marsh species) and *L. binervosum* (G. E. Sm.) C. E. Salmon (a species from maritime shingle banks) by de Fraine (556). Primary structure diarch or triarch in *L. binervosum*; diarch or tetrarch in *L. bellidifolium*. The more mature root of *L. binervosum* exhibits the following features. **Cork** arising in the pericycle, consisting of a few layers of cells with dense, homogeneous, tanniniferous contents. Primary **cortex** including a single layer of very large cells, the remainder being composed of much smaller cells. Secondary cortex containing an almost continuous band of sclerenchymatous fibres, and other scattered, sclerenchymatous elements. **Endodermis** with casparian thickenings well defined. **Pericycle** consisting of a single layer of thin-walled cells. Secondary **xylem** usually devoid of parenchyma and rays, the latter being found only near the leaf traces. **Tannin** abundant in the cork, medullary rays, and phloem. Cultivation in garden soil induced the formation of less sclerenchyma, more cortical parenchyma, and, in the xylem, the development of parenchyma in the ground tissue. Root structure of *L. bellidifolium* similar to that of *L. binervosum* except for the broader cork and phloem, the absence of sclerenchyma except near the junction with the stem, the spongy nature of the secondary cortex, the mainly parenchymatous ground tissue, and broad primary and secondary rays in the xylem.

ECONOMIC USES

Species of *Limonium* and *Plumbago* are cultivated for decorative purposes.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Acantholimon,* Aegialitis, Armeria,* Ceratostigma,* Goniolimon, Limoniastrum,* Limonium, Plumbago,* Vogelia.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

(Acantholimon), (Aegialitis), (Limoniastrum), Plumbago.

LITERATURE

(i) *On General Anatomy*

de Fraine **556**, Ruhland **1967**, Sayeedud-Din **2009**.

(ii) *On Wood Structure*

Pfeiffer, H. **1712**, Record **1843**, **1851**.

181. PRIMULACEAE

(FIG. 193 on p. 842; FIG. 197 on p. 860)

SUMMARY

Mainly herbs, but some species tend to be shrubby. The family occurs chiefly in temperate regions in the northern hemisphere. The herbaceous species exhibit several more or less distinct morphological types with corresponding anatomical differences in the axis. In the first of these forms the plant consists of a short shoot with radical leaves, e.g. *Primula*; in the second there is a rhizome with leafy shoots, e.g. in *Lysimachia*; the third type consists of cushion plants with acicular leaves, e.g. *Aretia*. The **hairs** are uniseriate, branched or capitate. The capitate hairs secrete the crystalline material forming the 'bloom' on the leaves of *Primula farinosa* Linn., whilst the secretion from the hairs of *P. obconica* Hance, *P. sinensis* Lindl., and a few other species irritates the skin of human beings sufficiently to cause dermatitis. The **stomata** are variously distributed in different species of *Primula*. The **vascular system** of the axis exhibits a wide range of structure. In many herbaceous species a ring of separate bundles surrounds the pith. In some of the primulas, especially those which are popularly known as auriculas, there are bundles or steles arranged in concentric rings or irregularly distributed as seen in transverse sections, but they anastomose frequently to form a complex network. In the more woody members of the family, especially those which are perennial, the bundles are so close together that there is a more or less continuous ring of phloem and xylem. **Secretory cells** and **cavities** with bright red or reddish contents occur in a few genera, particularly *Lysimachia*. The teratological structures known as **'Tree Cyclamens'** which develop in *Cyclamen persicum* Mill., consist of tissues of mixed origin and have been interpreted by Heitzman (945) as arising by the fusion of the primordia of petioles with flowering shoots of the third order. **Anomalous structure** occurs in *Hottonia* and in *Primula* p.p.

LEAF

Usually dorsiventral; centric in xeromorphic species. **Hairs** consisting of the types shown in Fig. 193 E–I. (i) Uniseriate, composed of a few or many cells, with thin or thick walls, e.g. in *Androsace* (Fig. 193 E). (ii) Segmented hairs with blunt ends recorded by Braun (264) in a few species of *Androsace*, *Cyclamen*, and *Lysimachia*. (iii) Multicellular, branched hairs present in species of *Androsace* (Fig. 193 F) and *Aretia*. (iv) Capitate glandular hairs (Fig. 193 H–I), with stalks of various lengths composed of a few or more cells and provided with unicellular or vertically divided heads, occur widely. Heads, according to Braun (264), unicellular in *Anagallis*, *Androsace*, *Primula*, *Soldanella*. These hairs produce the crystalline secretion forming the well-known 'bloom' on the leaves of *Primula farinosa* Linn. and related species. The secretion from the hairs of *Primula sinensis* Lindl., *P. obconica* Hance, and other closely related species is capable of inducing human dermatitis. **Epidermis** nearly always consisting of cells with sinuous anticlinal walls except in xeromorphic species. **Stomata** generally ranunculaceous and never accompanied by subsidiary cells; confined to either, or present on both, surfaces in different species; absent from or infrequent on submerged leaves of *Hottonia*; confined to 2 furrows on the lower surface in the xerophilous species *Dionysia revoluta* Boiss.; 133 per sq. mm. on the lower and 36 per sq. mm. on the upper surface of *Primula nivalis* Pall. according to Chkhubianishvili (397). Macleod (1469) has recorded the following information concerning the stomatal distribution in *Primula*, the names of the sections of the genus being those published by Wright Smith and Forrest (2154). Species with stomata confined to the lower surface belong to the Revolutae, those with stomata exclusively on the upper surface to the Involutae. Species with stomata on both surfaces occur in both Revolutae and Involutae. Stomata are believed by Macleod to arise on the portion of the leaf exposed to the greatest tension during expansion, but other factors also determine their distribution. **Hydathodes** frequent, usually situated at the end of the median vein and sometimes at the termination of the lateral veins as well. **Mesophyll** generally including 1–2 layers of palisade cells, varying considerably in length; arm-palisade cells recorded in species of *Lysimachia* and *Trientalis*. Mesophyll composed of a homogeneous tissue of small cells with few intercellular spaces in *Primula nivalis*. Macleod (1469) noted the following arrangements of air cavities in the mesophyll in different species of *Primula*. (*a*) Mainly confined to the upper mesophyll; (*b*) occurring throughout the mesophyll; (*c*) chiefly situated in the lower mesophyll; (*d*) absent. Types *a* and *b* noted amongst the Involutae and *c* and *d* mostly amongst the Revolutae. Vascular bundles of the **veins** generally surrounded by a parenchymatous sheath or endodermis, but, according to Solereder, occasionally accompanied by sclerenchyma. **Petiole** (Fig. 197 A–C), where distinctly differentiated, said by Solereder to be provided with only 1 bundle at the base. Petiole, in transverse sections through the distal end, exhibiting a crescentic system of separate vascular bundles in the few leaves of *Androsace*, *Dodecatheon*, *Lysimachia* (Fig. 197 A), and *Primula* (Fig. 197 C) examined at Kew. Median bundle in the same species larger than the remainder; collateral in *Androsace* and *Lysimachia*; strongly crescentic in *Primula veris* Linn. Median bundle circular with central parenchyma in species of *Dodecatheon* and *Primula vulgaris* Huds., the lateral strands in the same species devoid of parenchyma in the centre of the xylem. A small, solitary, collateral, median strand noted in *Glaux maritima* Linn., and a single, deeply crescentic bundle in *Cyclamen neapolitanum* Tenore (Fig. 197 B). **Secretory cells** with reddish-brown contents, appearing as dots in the leaves, recorded in a few species of *Anagallis* and *Centunculus*. **Secretory cavities,** each with an epithelium and filled with bright-red crystalline material, said to be confined to certain species of *Androsace*, *Coris*, *Lubinia*, *Lysimachia*, *Samolus*. Intercellular spaces filled with a similar secretion but not lined with epithelium also occur in *Lysimachia*. For particulars concerning the development of secretory glands in *L. vulgaris* Linn. see Guttenberg's (852) article. Secretory receptacles of all of these types often present in the axis as well as the leaf. Cavities with mucilaginous linings also occur in the leaf of certain species of *Primula*. **Crystals** of calcium oxalate generally absent. Further details concerning **interspecific differences,** especially with reference to hair structure, recorded by Braun (264). The adventitious leaves of *Cyclamen persicum* Mill. arise, according to Boodle (235); (i) strictly exogenously in the absence of periderm; (ii) below the cork when the latter is present; (iii) from deep-seated cortical cells beneath cut surfaces.

AXIS

STEM AND RHIZOME (Fig. 197 D–F)

Aerial stems sometimes winged, e.g. in *Anagallis* (Fig. 197 E). **Cork** rarely developed, relatively superficial in species of *Dodecatheon*, *Lysimachia*, *Primula*; sometimes pericyclic in *Douglasia* and certain species of *Primula*. Primary **cortex** usually chlorenchymatous and often lacunar in the species examined at Kew. Well-developed intercellular spaces recorded by Solereder in species from moist habitats, particularly in the aquatic *Hottonia* (arranged in several circles, separated from one another by a single row of cells), and also in the halophyte *Glaux maritima* Linn. **Endodermis** usually well defined. **Pericycle** frequently containing a sclerenchymatous ring, but the more detailed information concerning the occurrence of this character as given by Solereder needs further investigation. Pericyclic sclerenchyma absent from *Anagallis arvensis* Linn. (Fig. 197 E), but pericycle including a continuous ring of small, thick-walled fibres in *Glaux maritima* Linn. (Fig. 197 F), *Lysimachia vulgaris* Linn. (Fig. 197 D), and *Samolus valerandi* Linn. **Vascular bundles** usually widely spaced and arranged in a circle around the central pith, e.g. in *Anagallis arvensis* (1 bundle opposite each of the 4 angles of the stem) (Fig. 197 E), *Lysimachia vulgaris* (bundles resembling those of the Ranunculaceae) (Fig. 197 D), and *Samolus valerandi* (bundles very small). Elements between the separate bundles sometimes sclerenchymatous, e.g. in *Lysimachia vulgaris*. Bundles sufficiently close together to form a closed ring in certain species of *Androsace*, *Ardisiandra*, *Bryocarpum*, *Coris*, *Cortusa*, *Cyclamen*, *Dodecatheon*, *Glaux* (Fig. 197 F), *Hottonia*, *Kaufmannia*, *Lysimachia*, *Primula*, *Soldanella*, *Stimpsonia*; separated from one another and individually distinct in other species of *Androsace* and *Primula*; according to Solereder phloem continuous but xylem groups distinct in *Trientalis*. Mature xylem of *Lysimachia hillebrandi* Hook. f. including extremely small vessels arranged in long radial multiples and provided with

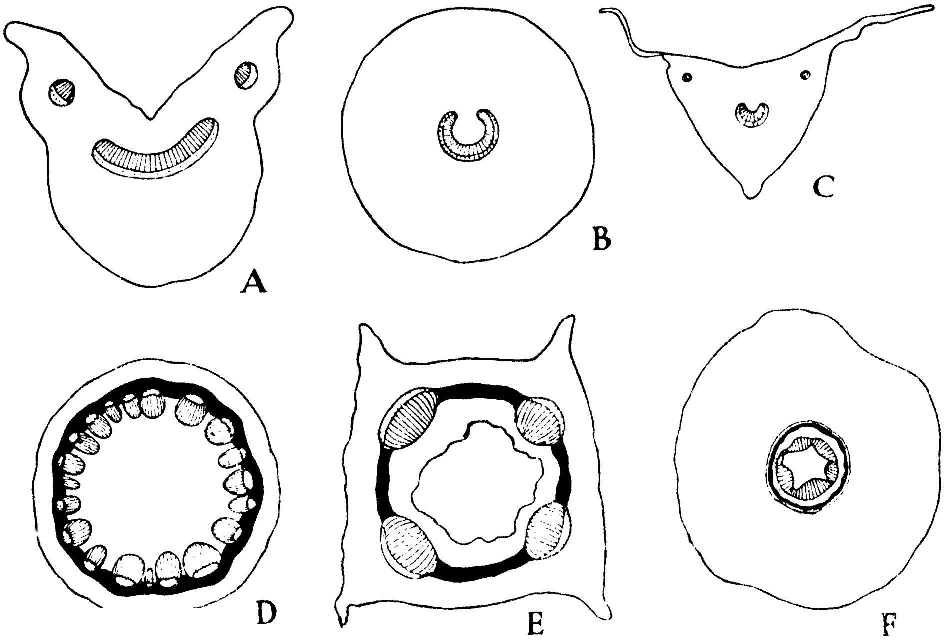


Fig. 197. *PRIMULACEAE*

A, *Lysimachia vulgaris* Linn. Petiole × 28. B, *Cyclamen neapolitanum* Tenore. Petiole × 15. C, *Primula veris* Linn. Petiole × 8. D, *Lysimachia vulgaris* Linn. Stem × 28. E, *Anagallis arvensis* Linn. Stem × 19. F, *Glaux maritima* Linn. Stem × 28.

simple perforations. Intervascular pits small, alternate. Xylem parenchyma and rays absent from the same species; fibres provided with numerous simple or indistinctly bordered pits on all walls. Vessels with simple perforations also recorded in *Androsace* and *Lysimachia* and noted in *Anagallis arvensis*. Groups of sclerenchyma present in the cortex and/or pith of certain primulas as well as of species of *Cortusa*, *Samolus*, *Soldanella*. **Secretory cells** with unidentified contents noted at Kew in the unlignified tissues of *Anagallis arvensis*, *Glaux maritima*, *Lysimachia vulgaris*, *Samolus valerandi*. For secretory elements see also under 'Leaf'. **Cushion plants,** such as occur in *Androsace* (pro parte), *Aretia*, *Coris*, *Dionysia*, and *Douglasia*, exhibit the following features. (i) Cortex becoming detached from the inner tissues owing to radial and tangential divisions of the endodermal cells. (ii) Phloem well developed, collenchymatous.

PEDUNCLE

Pericycle including a continuous zone of small fibres in '*Androsace chumbyi* Hort' and *Primula vulgaris* Huds.; no pericyclic sclerenchyma seen in the few species of *Cyclamen*, *Dodecatheon*, and *Primula* examined at Kew. **Vascular system** consisting of a circle of individually distinct bundles in at least a few species of *Androsace* (bundles like those of the Ranunculaceae), *Cyclamen*, *Dodecatheon*, and *Primula*. Scattered **secretory cells,** with unidentified contents, noted in the unlignified tissues of species of *Androsace* and *Primula*.

ROOT

Murray (1575) has recorded the following information concerning the root structure of *Primula*, the names of the species and groups being those used by Wright Smith and Forrest (2154). Cells of the **piliferous layer** prolonged to form short hairs in *P. veris* Linn. and *P. vulgaris* Huds., both belonging to the section Vernales; root hairs absent from members of the sections Amethystina, Muscarioides, and Candelabra; lignified root hairs present in certain species in the section Auricula with roots partly exposed in the crevices of limestone rocks. **Exodermis** consisting of isodiametric or radially elongated, thin-walled, or suberized cells. **Endodermis** composed of tangentially elongated and radially divided cells in numerous species, including those in the sections Bullatae, Cortusoides, Malacoides, Obconica, Sinensis, and Verticillata. Species with divided endodermal cells also show development of secondary tissues in the vascular cylinder in correlation with their growth in crevices or on ledges of limestone rocks. Secondary **xylem** in the form of cuneate bands separated by medullary rays composed of tangentially divided, parenchymatous cells in *P. floribunda* Wall., *P. forrestii* Balf. f., *P. redolens* Balf. f. et Ward, and *P. verticillata* Forsk. Vascular cylinder in all herbaceous species examined provided with 2–11 exarch xylem poles. **Pith** composed of a broad zone of isodiametric or polygonal, parenchymatous cells. **Secretory cells,** with reddish-brown contents, recorded by Solereder in various species of *Lysimachia*.

ANOMALOUS STRUCTURE

(i) *Hottonia*

Vascular system consisting of a ring of bundles surrounding a pith, with intercellular spaces replacing some of the primary groups of vessels. According to H. Schenck (in Solereder) the apparent pith consists of wood parenchyma, the first vessels arising in this region.

(ii) Species of *Primula*, particularly of the *Auricula* type

Vascular system consisting of a single ring of bundles for a distance of several internodes above the cotyledons, but later dividing to form numerous vascular bundles, sometimes with a central pith (steles), arranged in 1 or more rings or irregularly distributed. Other secondary bundles subsequently arising in the pericyclic region of the primary bundles. The number and arrangement of the steles exhibits a wide range of variation, and is possibly of specific diagnostic value. The whole vascular system constitutes a complex network owing to fusions between the individual bundles or steles. For further details see Solereder.

TAXONOMIC NOTES

The vascular anatomy of the flower of the Primulaceae has been investigated by Douglas (608), who concludes that 'the vascular pattern and presence of locules at the base of the ovary point to the fact that the present much reduced flower of the Primulaceae has descended from an ancestor which was characterized by a plurilocular ovary and "axial" placentation. This primitive flower might well be found in a centrospermal stock, as Wernham, Bessey, and Hutchinson have suggested.'

Murray (1575) found that *Primula* can be divided into groups based on differences in the anatomical structure of the root, and that these groups agree closely with the taxonomic sections of the genus based on exomorphic characters. The same author has also suggested that the anatomical features of the root may serve as a valuable guide to the taxonomist in determining relationship when this is doubtful.

ECONOMIC USES

No member of the family has any well-established economic use, although medicinal properties have been attributed to a few species of *Primula*. Many species, especially of *Primula*, are cultivated for decorative purposes.

GENERA DESCRIBED

Anagallis,* Androsace,* Ardisiandra, Aretia, Bryocarpum, Centunculus, Coris, Cortusa, Cyclamen,* Dionysia, Dodecatheon,* Douglasia, Glaux,* Hottonia, Kaufmannia, Lubinia, Lysimachia,* Primula,* Samolus,* Soldanella, Stimpsonia, Trientalis.

* Represented in the Kew slide collection.

LITERATURE

On General Anatomy

Boodle **235**, Braun **264**, Chkhubianishvili **397**, Douglas **608**, Guttenberg **852**, Heitzman **945**, Macleod **1469**, Matthiesen **1457**, Murray **1575**, Smith and Fletcher **2153**, Smith and Forrest **2154**.

182. MYRSINACEAE

(FIG. 198 on p. 864; FIG. 199 on p. 866; FIG. 200 on p. 868)

SUMMARY

(i) GENERAL

A mainly tropical family consisting mostly of trees and shrubs. The habit of the Theophrasteae is unusual. Thus *Clavija* somewhat resembles a palm, since the plants have a long, slender, unbranched, leafless trunk bearing a terminal, rosette-like head of leaves. *Theophrasta* is similar in habit but smaller in size, whilst *Deherainia* consists of a very short stem bearing a rosette of leaves just above soil-level. *Jacquinia* is much more branched. Simple **hairs** are infrequent, although uniseriate types occur rarely. Various kinds of branched hairs are characteristic of *Jacquinia*, whilst capitate and glandular trichomes, sometimes depressed below the leaf surface, are more widely distributed. The **leaf margin** in the Theophrasteae is also frequently supported by 1 or more strands of sclerenchyma, or by a vascular bundle surrounded by sclerenchyma. The leaf of *Ardisia crispa* A. DC. is particularly interesting because of the occurrence of cavities in the margins filled with particulate matter which has been variously interpreted as protein material or bacteria. The **mesophyll** of the Theophrasteae is characterized by sclerenchymatous elements, variously arranged in different species, and generally situated immediately below the epidermis. The **cork** originates superficially in all species in which it has been examined. The **pericycle** contains a varying amount of sclerenchyma in different genera and species. **Secretory cells** and **cavities,** with yellow or reddish-brown contents, are frequent in the leaf except in the Theophrasteae. **Canals** containing a similar secretion are also to be found in the cortex and pith of the axis in the same genera. Both solitary and clustered **crystals** occur.

(ii) WOOD

Vessels moderately small, commonly in radial multiples of 3 or 4 cells and irregular clusters, occasionally with a radial or slight tangential pattern, perforation plates usually simple only, but with some scalariform plates in a few species, intervascular pitting small and alternate, pits to parenchyma similar or elongated horizontally. Members of medium length to very short. **Parenchyma** typically paratracheal and sparse, a few cells to narrow sheaths round the vessels. **Rays,** except in *Maesa*, typically multiseriate only, 4–30 cells wide, and sometimes extremely broad (400 μ wide or more), very high, heterogeneous, composed entirely of square or upright cells in some species, but occasionally almost homogeneous; large cysts present in several genera. **Fibres** typically septate, except in the Theophrasteae, and with simple pits, but septa occasionally absent or rare and pits sometimes with small borders; very to extremely short.

LEAF

Generally dorsiventral except sometimes in the Theophrasteae. **Hairs** mostly of the types in Fig. 198. (i) Uniseriate hairs rare, recorded in *Deherainia* and *Jacquinia*. (ii) Peculiar, branched, sclerosed hairs occur in *Jacquinia armillaris* Jacq. (Fig. 198 C) and related species. Other forms of forked or branched, multicellular trichomes also occur in the same genus. (iii) Peltate trichomes (Fig. 198 D and E) recorded in *Aegiceras*, *Ardisia*, *Clavija*, *Conomorpha*, *Deherainia* (with 16 cells in the head in *D. smaragdina* Decne. (Chandler 377)), *Hymenandra*, *Jacquinia*, *Myrsine*, *Theophrasta*; those of *Aegiceras* and *Clavija* depressed below the leaf surface (Fig. 198 A, B, F, G). **Epidermis** consisting of cells with straight (particularly in the Theophrasteae) or sinuous anticlinal walls; gelatinized in species of *Ardisia*, *Conomorpha*, *Cybianthus*, *Parathesis*, *Wallenia*. Walls of the epidermal cells provided with local thickenings in *Clavija boliviensis* Mez., or calcified in *Theophrasta jussieuii* Lindl.

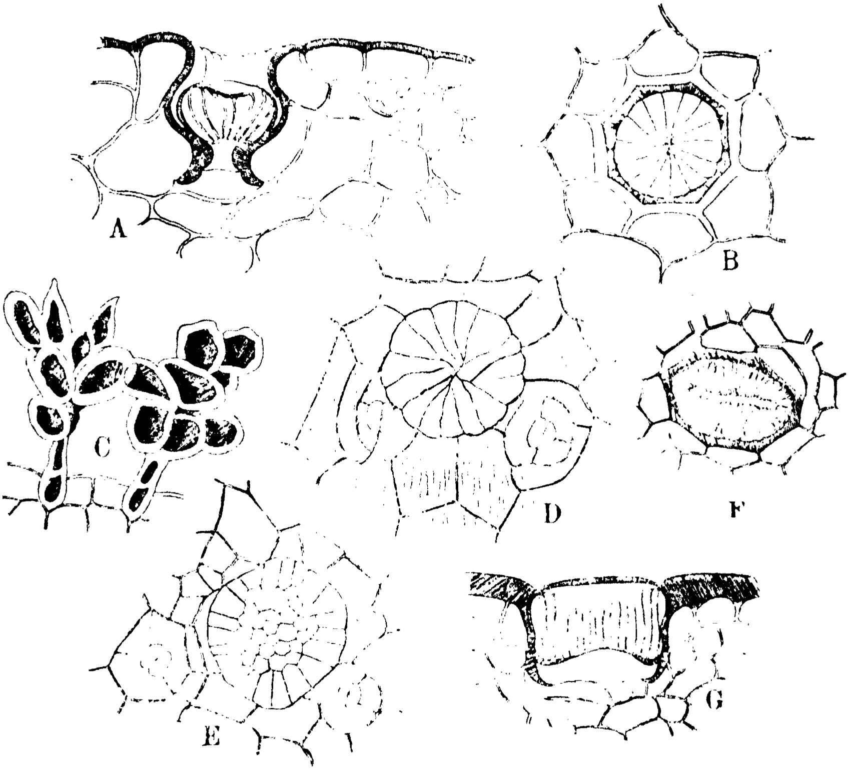


FIG. 198. *MYRSINACEAE*

A–B, Depressed glandular hair of *Clavija caloneura* Mart., A, in transverse section, B, in surface-view. C, Hairs from the surface of a branch of *Jacquinia armillaris* Jacq. D, Peltate hair of *Ardisia javanica* A. DC. E, Peltate hair of *Ardisia macrocarpa* Wall. F–G, Glands of *Aegiceras majus* Gaertn.—By Solereder.

Hypoderm of aqueous tissue present beneath the upper and a smaller amount beneath the lower epidermis in *Aegiceras majus* Gaertn. according to Mullan (1569), and beneath the upper epidermis of *Clavija* spp. according to Mez (1510). **Stomata** confined to the lower surface, surrounded by 3 or more (cruciferous-ranunculaceous) cells. The nodular crenate **leaf margin** of *Ardisia crispa* A. DC. is remarkable for the occurrence of internal, glandular cavities filled with material which has been variously interpreted as consisting of bacteria or protein material. These cavities and the bacteria in them have been investigated by Miehe (1513, 1514) both from the microscopical and physiological standpoints. The bacteria occur in some but not in all of the seeds, they are situated at the growing-point at the time of germination, after which they become established in special organs in the leaf primordia, and multiply in the intercellular spaces. When the flower is formed they become located in the ovary and pass thence to the seed. Similar structures occur in other species of *Ardisia*, especially those belonging to the section *Crispardisia*, as well as in *Ambylanthopsis* and *Ambylanthus*. Since some aspects of the life-history of the bacteria, and the physiological significance of the apparent symbiotic relationship between *Ardisia* and the bacteria are not fully understood, the subject might repay further investigation. Leaf margins of the Theophrasteae supported by 1 or more sclerenchymatous strands, or, in species of *Clavija*, by a vascular bundle surrounded by sclerenchyma.

Mesophyll of *Clavija* (pro parte), *Deherainia*, *Jacquinia*, *Theophrasta*, and *Weigeltia schlimii* Mez. containing sclerenchymatous fibres beneath the upper and lower epidermis, the fibres sometimes lying approximately parallel to the lateral veins and appearing very distinct in dried leaves of *Clavija* and *Theophrasta*. The more detailed occurrence and distribution of the fibres is possibly of value for the identification of genera and species. Hypodermal sclerenchyma on the 2 sides of the leaf, especially in *Theophrasta*, united together and also to the sclerenchyma sheaths of the veins by 'spicular fibres'. Vascular bundles of the **veins** accompanied by a sclerenchymatous sheath only in certain genera especially in the Theophrasteae. Median vein containing 2 or more bundles in *Clavija*, *Neomezia*, and *Theophrasta*, but with only a single bundle in *Deherainia* and *Jacquinia*. **Petiole** (Fig. 199 A–C and E–H), in transverse sections through the distal end, in species of *Ardisia* (Fig. 199 C), *Myrsine* (Fig. 199 A), *Rapanea* (Fig. 199 E), and *Stylogyne* (Fig. 199 B) examined at Kew, exhibiting a median, crescentic vascular strand, varying in shape and in the extent to which dissected into separate strands in different genera and species. A continuous or slightly dissected, crescentic strand, strongly supported by sclerenchyma, also noted in *Deherainia smaragdina* Decne. (Fig. 199 H) and *Jacquinia* sp. (Fig. 199 F). Vascular system at the base of the petiole of *Deherainia smaragdina* in the form of 3 separate strands according to Chandler (377). Petiolar vascular system in *Clavija ornata* very complex (Fig. 199 G). 'Cortical' region of the petiole in the same species of *Clavija*, *Deherainia*, and *Jacquinia* including groups of fibres. Schizogenous **secretory cavities** with yellow or reddish-brown, crystalline, homogeneous or granular contents, sometimes appearing as dots in the leaf, recorded in species of *Aegiceras*, *Ardisia*, *Conomorpha*, *Cybianthus*, *Embelia*, *Grammadenia*, *Hymenandra*, *Maesa*, *Myrsine*, *Parathesis*, *Pimelandra*, *Wallenia*. Secretory cavities noted at Kew in the 'cortical' region of the petiole in species of *Ardisia*, *Myrsine*, *Rapanea*, *Stylogyne*. Cavities sometimes crowded at the margin of the leaf and somewhat elongated in shape, e.g. in *Grammadenia* and *Maesa*. Similar cavities or canals also occur in the pith and/or primary cortex of the axis. **Secretory cells** also recorded in *Cybianthus* and in the pith of *Maesa*. Tannin said by Mullan (1569) to be abundant in *Aegiceras majus*. **Crystals** mostly solitary or clustered; small prisms or acicular crystals present in the epidermis of *Clavija* (pro parte), *Deherainia*, *Jacquinia*, serve as a diagnostic character for these genera.

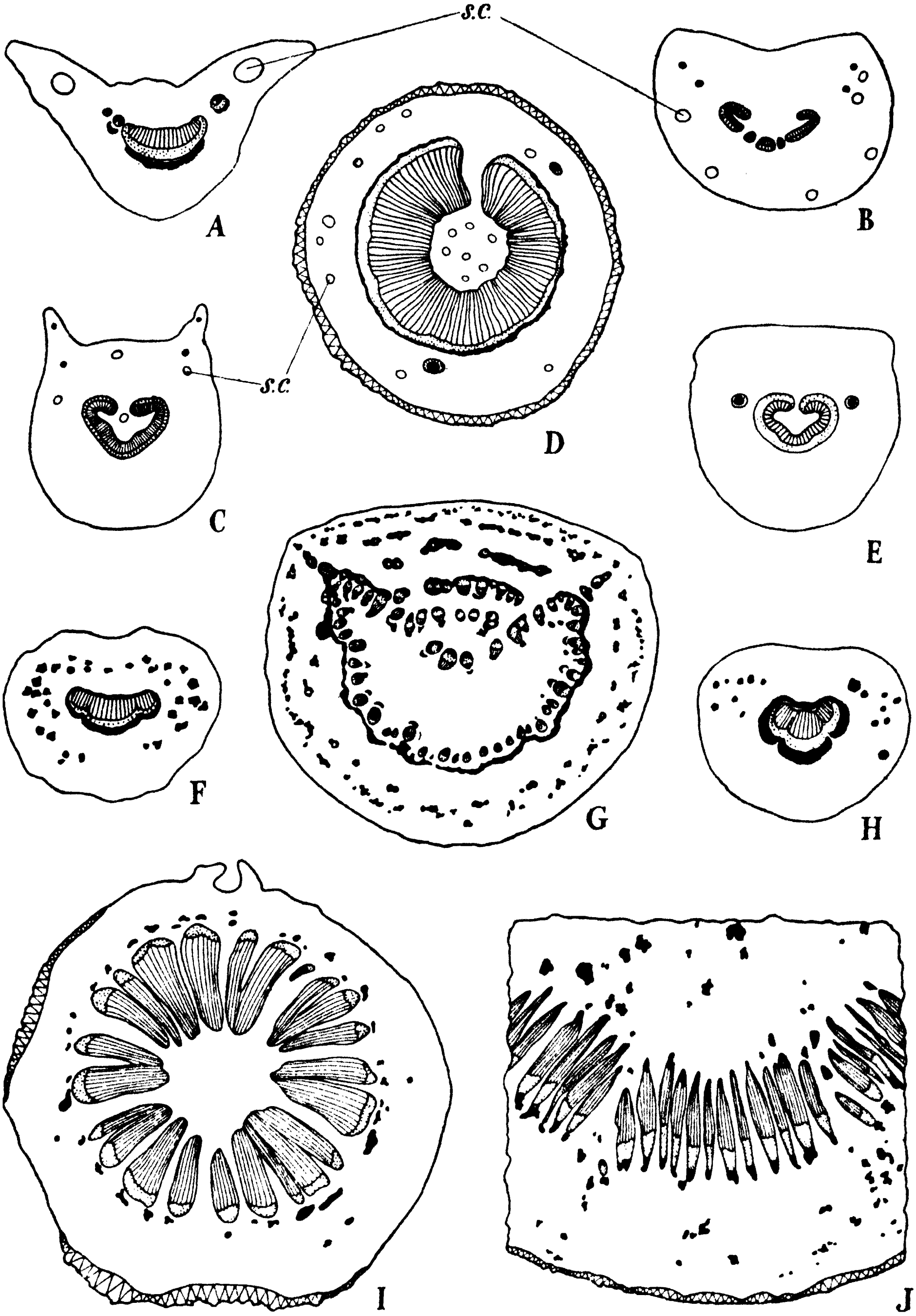


Fig. 199. *MYRSINACEAE*

A, *Myrsine africana* Linn. var. *retusa* A. DC. Petiole × 37. B, *Stylogyne laevigata* Mez. Petiole × 10. C, *Ardisia crispa* A. DC. Petiole × 15. D, *Stylogyne laevigata* Mez. Stem × 11. E, *Rapanea laetivirens* Mez. Petiole × 15. F, *Jacquinia* sp. Petiole × 13. G, *Clavija ornata* D. Don. Petiole × 7. H, *Deherainia smaragdina* Decne. Petiole × 12. I, *Jacquinia* sp. Stem × 15. J, *Clavija ornata* D. Don. Part of stem × 7.

s.c. Secretory canals or cavities.

AXIS

STEM (Fig. 199 D, I, and J)

Surface of the stems of *Aegiceras majus* Gaertn. greyish and covered with wax; younger portions reddish-brown. **Epidermis** in the same species consisting of 2 layers of cells; the inner one tanniniferous when young, but serving for water storage when older. **Cork** arising in the epidermis or sub-epidermis of *Aegiceras*, *Clavija* (Fig. 199 J), *Jacquinia* (Fig. 199 I), *Maesa*, *Myrsine*, *Rapanea*, *Stylogyne*. Cork cells with refractive contents recorded in *Jacquinia armillaris* Jacq. Primary **cortex** sometimes containing stone cells in *Clavija* (Fig. 199 J) and, according to Mullan (1569), vertically elongated spicules with pitted walls in *Aegiceras majus*. Cells of the cortex and pith of *Myrsine africana* Linn. show a deep indigo-blue coloration when treated with caustic soda solution. **Pericycle** often containing isolated arcs of sclerenchymatous fibres, e.g. in species of *Ardisia*, *Clavija*, *Jacquinia*, an almost closed ring of fibres in *Maesa*, and an almost or quite continuous composite ring in species of *Aegiceras*, *Ardisia*, *Conomorpha*, *Embelia*, *Jacquinia*, *Myrsine*, *Rapanea*, *Stylogyne*. **Xylem** in the few species of *Ardisia*, *Myrsine*, *Rapanea*, and *Stylogyne* examined at Kew in the form of a continuous cylinder traversed by narrow rays (see, however, 'Wood', below); including vessels with simple perforations. Xylem in species of *Clavija* (Fig. 199 J), *Deherainia*, *Jacquinia* (Fig. 199 I) (all members of the Theophrasteae) traversed by wide primary rays, the latter becoming lignified in sufficiently mature stems. Vessels in these genera with simple perforations. Occasional scalariform plates also recorded in the family. **Secretory cells, cavities,** or **canals** of the same types as described under 'Leaf'. Secretory cells abundant in the unlignified tissues in the few species of *Ardisia*, *Myrsine*, *Rapanea*, and *Stylogyne* examined at Kew, and also, according to Mullan (1569), in *Aegiceras majus*; none seen in the corresponding positions in *Clavija*, *Deherainia*, *Jacquinia* (Theophrasteae). Secretory canals also observed in the cortex in a few species of *Ardisia*, *Myrsine*, *Stylogyne*, and in the pith as well in *Ardisia* (in 1 of the 2 species examined) and *Stylogyne*; secretory canals also noted by Mullan (1569) in the cortex and pith of *Aegiceras majus*. Cluster **crystals** seen in the cortex and pith of *Ardisia*, *Rapanea*, and *Stylogyne*; none observed in species of *Clavija*, *Deherainia*, *Jacquinia* (Theophrasteae).

WOOD (Fig. 200)

Vessels typically moderately small (50–100 μ mean tangential diameter), sometimes slightly smaller, particularly in *Aegiceras corniculatum* Blco. and genera of the Theophrasteae; commonly in radial multiples of 3 or 4 cells and in irregular groups, sometimes with an oblique or radial pattern, e.g. in *Ardisia oblanceolata* Standl., *Conomorpha magnoliifolia* Mez., *Cybianthus*, *Stylogyne laevis* (Oerst.) Mez. (Fig. 200 I), and *Wallenia laurifolia* (Jacq.) Sw., and sometimes with a tangential pattern in *Aegiceras* (1154); mostly solitary and in pairs and without any pattern in *Deherainia* and *Theophrasta* except near the pith; seldom in contact with the rays except in *Maesa*; typically 20–40 per sq. mm., sometimes fewer than 10 per sq. mm., e.g. in *Ardisia lanceolata* Roxb. and in occasional specimens of *Rapanea melanophleos* (L.) Mez., and more than 40 per sq. mm. in *Aegiceras corniculatum*; semi-ring-porous in *Jacquinia*; spiral thickening reported in *Maesa doraena* Bl. (2158).

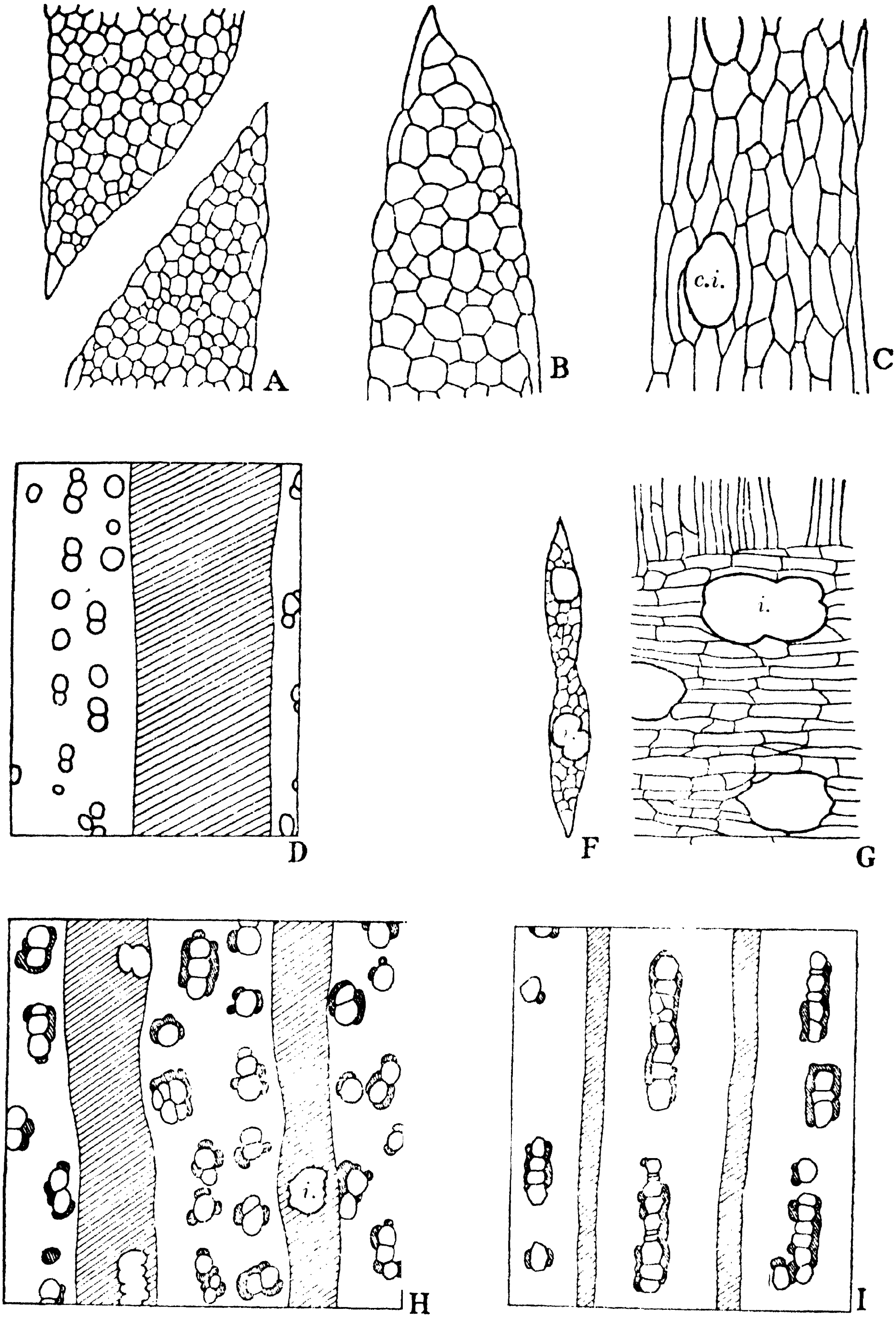


FIG. 200. *MYRSINACEAE*

A, *Jacquinia revoluta* Jacq. B, *Rapanea melanophleos* Mez. C, *Ardisia lanceolata* Roxb. Ray showing crystals. D, *Clavija longifolia* Mez. E, *Maesa ramentacea* Wall. F, '*Aegiceras floridum* Roem. et Schult.' Ray in tangential section. G, ditto. Ray in radial section. H, *Rapanea leuconema* Mez. I *Stylogyne laevis* Mez.

c.i. Crystalliferous idioblast. *i.* Cysts formed from idioblasts.

Perforation plates usually exclusively simple, but with some scalariform plates in *Weigeltia* and, according to Solereder, in *Ardisia crenulata* Vent., *Maesa doraena*, *M. indica* Wall., and *Myrsine* p.p., and, according to Janssonius (1154), in *Maesa forbesii* Mez. and *Pimelandra macrophyll* Koord. et Valet. and occasionally in the side walls in *Ardisia marginata* Blume. Intervascular pitting small (sometimes minute) and alternate, showing considerable variation in size even between species of the same genus, sometimes with marked striations owing to coalescent apertures, e.g. in *Ardisia compressa* H. B. et K.; pits to parenchyma usually similar to the intervascular pitting, but sometimes much elongated horizontally, e.g. in *Ardisia lanceolata* and *Stylogyne laevis*. Typically without contents, but with tyloses in *Myrsine tenuifolia* Koord. et Valet. (1154). Storied in *Aegiceras*. Mean member length 0·2–0·5 mm. **Parenchyma** typically paratracheal and usually sparse; extremely sparse in, or absent from, *Clavija*, *Deherainia*, *Maesa*, and *Theophrasta*, consisting of a few cells (scanty) to narrow sheaths (vasicentric) round the vessels, commonly flanking the radial walls of multiples and sometimes more abundant on the tangential walls (Fig. 200 I); sometimes with a few cells scattered among the fibres (1154); Williams (2426) refers to the parenchyma in *Cybianthus venezuelensis* Mez. as 'sparingly diffuse', and Record and Hess (1886) describe the parenchyma of the family as 'very sparingly paratracheal and diffuse'. Often filled with dark gummy contents. Strands usually of 2–4 or 4 cells, with some fusiform cells in *Aegiceras* and *Jacquinia*. Sometimes locally storied in *Aegiceras*, where sufficiently abundant. **Rays** in *Maesa* of 2 distinct sizes, uniseriate and multiseriate, but typically multiseriate only in the other genera, though with a few uniseriate rays in *Aegiceras* and *Cybianthus* (2426). Very variable in width, 3–6 cells wide in *Aegiceras* (most species), *Cybianthus*, *Deherainia* (very small), and *Maesa*, 6–10 cells wide in *Aegiceras floridum* R. et S. (1649), *Discocalyx*, *Pimelandra* (1154), *Rapanea* p.p., *Stylogyne*, and *Weigeltia*, more than 10 cells and up to 300–500 μ wide in some species of *Ardisia*, *Clavija*, *Conomorpha*, *Jacquinia*, *Myrsine*, *Rapanea*, and *Theophrasta*, and up to 30 cells wide in some specimens of *Rapanea melanophleos* Aubl. and in *Aegiceras corniculatum* (1154); very high (often 10 mm. or more), except in *Aegiceras* (Fig. 200 F) and *Maesa*, and with the large rays commonly dissected into shorter units in *Jacquinia* (Fig. 200 A); the uniseriate rays of *Maesa* composed of high upright cells and often as high as the multiseriate rays, those of *Aegiceras* short and composed of mixed procumbent and square or short upright cells; typically 1–4 rays per mm., but about 10 per mm. in *Maesa*; usually heterogeneous with 1–4 marginal rows (often partly biseriate) of upright cells, but with 10 or more uniseriate rows in *Maesa* (Fig. 200 E), almost homogeneous in *Aegiceras* and *Jacquinia*. Sheath cells present except in *Aegiceras* and *Jacquinia*. Commonly with solitary crystals in the ordinary cells and sometimes in idioblasts, e.g. in *Conomorpha magnoliifolia*; often with gummy contents. Large thin-walled idioblasts, often grouped together and with the intervening walls broken down to form cysts, observed or reported in some species of *Aegiceras*, *Ardisia*, *Conomorpha*, *Grammadenia*, *Parathesis*, *Rapanea*, *Wallenia*, and *Weigeltia* (Fig. 200 F–H *i*). **Fibres** typically with small simple pits equally numerous on both radial and tangential walls, but with pits with small borders in *Ardisia* p.p. (1154), *Rapanea melanophleos*, and *Wallenia*. Usually septate, but septate fibres very rare or absent from

Aegiceras, *Clavija*, *Conomorpha* p.p., *Jacquinia*, and *Theophrasta* and not common in *Parathesis*. Walls usually moderately thick, very thick in some species of *Conomorpha* and *Rapanea*. Storied in *Aegiceras*. Length 0·3–0·9 mm., usually 0·7–0·9 mm., shortest in *Aegiceras*.

ROOT

The following particulars concerning the root of *Deherainia smaragdina* Decne. have been recorded by Chandler (377). **Root hairs** with remarkably thick cell walls, especially at their basal ends. **Cortex** composed of cells of very varied shape. **Endodermis** clearly defined. **Pericycle** fairly broad. **Phloem** in the form of V-shaped patches. Centre of the root consisting of a fairly wide **xylem** described as 'arranged in a somewhat spiral fashion from the centre'.

Root of the Mangrove plant *Aegiceras majus* Gaertn. described as follows by Mullan (1569). **Cortex** aerenchymatous, consisting of cells slightly elongated in a vertical direction and supported by cells with thickening plates, the latter with oval or ring-shaped slits. **Cork** arising superficially; composed of phelloid cells. Primary rays narrow. **Pith** consisting of polygonal, thick-walled, pitted cells. **Secretory cells** containing tannin and oil present in the phloem. Starch present in the ray cells. Liebau's (1368) earlier account of the young root of the same species mentions that the **endodermis** becomes highly lignified.

TAXONOMIC NOTES

(i) FROM GENERAL ANATOMY

The anatomical features recorded above suggest, at first sight, that the Theophrasteae are sufficiently distinct from the rest of the Myrsinaceae to be treated as a separate family, as in the Engler system. In particular the more dissected vascular system in the axis and absence of secretory elements differentiate the Theophrasteae from the rest of the family where abundant secretory elements and a continuous xylem were noted. It is quite possible, however, that these distinctions would be found to break down if more species had been examined. In this connexion it is noteworthy that broad rays occur in the mature secondary xylem of some of the Myrsinaceae which are not included in the Theophrasteae. If young stems of these species had been available for examination it is probable that an interrupted xylem cylinder would have been found. The relationship of the Theophrasteae to the rest of the Myrsinaceae is worthy of further anatomical investigation.

(ii) FROM WOOD STRUCTURE

Janssonius (1154) comments on the marked differences between *Maesa* and all the other genera and suggests that it should not be included in the family. He also compares groups of species of *Ardisia*, *Maesa*, and *Myrsine*, noting that (1) *Maesa blumei* and *M. virgata* are very similar, but unlike *M. forbesii*, (2) the species of *Myrsine* are very similar to each other, and (3) *Ardisia* divides into 2 groups, (*a*) with larger intervascular pitting and more procumbent cells in the rays, *A. marginata*, *humilis*, *obovata*, *fuliginosa*, and (*b*) *A. laevigata*, *purpurea*, *lurida*, *lanceolata*, *diversifolia*, *polyneura*, *zollingeri*, *javanica*.

Aegiceras has a more highly specialized structure than any of the other genera, with all elements except the rays storied and the rays almost homogeneous. The Theophrasteae appear to differ from the rest of the family only in the absence of septate fibres, which, however, are not present in all of the other genera.

ECONOMIC USES

Anthelmintic properties have been attributed to the fruits of *Embelia ribes* Burm. f. and *E. robusta* Roxb., especially in India and the Far East, but they are not regarded as well established. According to Lendner (1357) the leaves of several species of *Rapanea* have been substituted for Maté Tea (*Ilex paraguariensis* St. Hil. Family Aquifoliaceae, see p. 385). Lendner's account includes particulars of the anatomical structure of the leaves in question.

The large rays give the woods of this family an attractive figure on quarter-sawn surfaces, resembling that of the Silky Oaks, but the woods are of little commercial importance, being usually available only in small sizes. Record and Mell (1894) mention the woods of *Cybianthus* and *Conophora*, as being used to a limited extent in Brazil, and *Wallenia* in Cuba. Scott (2076) states that Boekenhout, *Myrsine melanophleos* R.Br., is used for furniture and panelling in South Africa.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Aegiceras, Ambylanthopsis, Ambylanthus, Ardisia,* Clavija,* Conomorpha, Cybianthus, Deherainia, Embelia, Grammadenia, Hymenandra, Jacquinia,* Maesa, Myrsine,* Neomezia, Parathesis, Pimelandra, Rapanea,* Stylogyne,* Theophrasta, Wallenia, Weigeltia.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Aegiceras, Ardisia, Clavija, Conomorpha, Cybianthus, Deherainia, Discocalyx, (Grammadenia), Jacquinia, Maesa, Myrsine, Parathesis, (Pimelandra), Rapanea, Stylogyne, Theophrasta, Wallenia, Weigeltia.

LITERATURE

(i) *On General Anatomy*

Chandler **377**, Lendner **1357**, Liebau **1368**, Mez **1510**, Miehe **1513**, **1514**, Mullan **1569**.

(ii) *On Wood Structure*

den Berger **182**, Brown, F. B. H. **282**, Chalk *et al.* **360**, Cozzo **494**, Dadswell and Record **533**, Howard **1088**, Janssonius **1154**, Kanehira **1206**, Panshin **1649**, Record **1783**, **1810**, **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**, Scott **2075**, **2076**, Tupper **2295**, Webber **2377**, Williams **2426**, **2430**.

183. SAPOTACEAE

(FIG. 201 on p. 874; FIG. 202 on p. 878)

SUMMARY

(i) GENERAL

The trees or shrubs which constitute this mainly tropical family are characterized especially by **laticiferous elements** which contain a refractive material resembling resin or gutta-percha. These elements, which are always present, occur in the leaf, where they usually accompany the veins, but are sometimes embedded in the mesophyll. In the stem they are to be found in the cortex, phloem, and pith. Two-armed **hairs** of somewhat varied types provide another very constant feature, but in some instances 1 of the arms is reduced or suppressed. The laticiferous elements and 2-armed hairs, when considered together, provide a valuable means of recognizing the family. Variously sized masses of a substance resembling rubber also occur in the mesophyll where they are most easily detected in dried material. The **mesophyll** is nearly always dorsiventral and commonly includes sclerenchymatous elements. The **stomata** are usually ranunculaceous and nearly always confined to the lower surface of the leaf. **Cork** in the axis arises superficially.

(ii) WOOD

Vessels typically in loose radial or oblique lines and often in multiples of 4 or more cells, perforations simple, intervascular pitting alternate and usually small, pits to parenchyma typically large, simple, and elongated; members usually of medium length but sometimes moderately or very long. **Parenchyma** apotracheal, banded, varying from broken uniseriate lines to regular, continuous multiseriate bands. **Rays** 1–6 cells wide, but most typically 2–3 cells wide, heterogeneous, sometimes markedly so. **Fibres** typically with simple pits, but pits occasionally bordered; usually of medium length, sometimes moderately to very long. **Vasicentric tracheids** present in several genera. **Silica** may be present in any of the elements other than the vasicentric tracheids.

LEAF

Usually dorsiventral; occasionally tending to be centric. **Hairs** consisting chiefly of thick- or thin-walled unicellular, 2-armed trichomes, but 1 of the arms sometimes reduced or absent; frequently secreting a resinous substance, especially on the lower side of the leaf. Hairs varying in shape in different genera and species, e.g. arms particularly long in some species of *Chrysophyllum* or with short arms in other species of *Chrysophyllum* and in species of *Madhuca* and *Pouteria*. Colour of the hairs golden-yellow, rusty-brown, or silvery-white. Simple, unicellular hairs abundant in *Delpydora*. Unicellular, overlapping, scale-like hairs recorded by Kienholz (1236) in *Sideroxylon ferrugineum* Hook. et Arn., especially on the lower surface of the leaf. **Cuticle,** especially on the lower surface of the leaf, strongly granulated, striated, or ridged, the ridges appearing as prongs or rods in transverse sections, e.g. in *Pouteria*. **Epidermis** consisting of cells with straight or sinuous anticlinal walls of varying thickness, frequently pitted; stated by Solereder to be gelatinized in a few species of *Bumelia*. Cells of the upper epidermis horizontally divided in *Chrysophyllum cainito* Linn. **Hypoderm** frequently present, its occurrence and distribution affording a valuable character for the recognition of genera and species. **Stomata** nearly always confined to the lower surface, although recorded on the upper side as well in a few species of *Chrysophyllum* and *Omphalocarpum*; usually ranunculaceous, but rubiaceous types recorded in a few species; sometimes deeply sunk in *Mastichodendron* and *Sideroxylon* (syn. *Calvaria*), rarely elevated above the epidermis in *Mimusops* and *Sarcosperma*. **Mesophyll** including 1 or more layers of palisade cells and spongy tissue with abundant intercellular spaces, or, more rarely, denser. Sclerenchymatous fibres in the mesophyll, recorded by Solereder in species of *Amorphospermum*, *Bumelia*, *Chrysophyllum*, *Labourdonnaisia*, *Madhuca*, *Manilkara* (syn. *Achras*), *Mimusops*, *Pouteria*, *Sideroxylon* (i.e. *Mastichodendron*) (fibres sometimes spirally thickened), *Synsepalum*. Vascular bundles of the small **veins** either embedded in the mesophyll or vertically transcurrent by means of sclerenchyma or collenchyma. **Petiole** (Fig. 202 A–D, F), in transverse sections through the distal end, exhibiting a flattened arc-shaped vascular strand in *Argania sideroxylon* Roem. et Schult. (Fig. 202 C) and *Bumelia lycioides* Willd., similar but with the ends of the strand somewhat incurved in *B. lanuginosa* Pers. (Fig. 202 A). Two small accessory strands present on the adaxial side of the median bundle in *B. lycioides*. Main vascular strand in the form of a closed, usually somewhat adaxially flattened cylinder in '*Illipe* (*Madhuca* Baehni) *longifolia*' (Fig. 202 F), *Chrysophyllum cainito* Linn., *Calocarpum mammosum* (L.) Pierre (syn. *Lucuma mammosa* (L.) Gaertn. (Fig. 202 D)), *Manilkara zapotilla* (Jacq.) Gilly (syn. *Achras sapota* Linn.), *Pouteria gardnerana* (A. D. C.) Radlk. (syn. *P. suavis* Hemsl.), *Sideroxylon* (*Mastichodendron* Baehni) *inerme* Linn., or a slightly interrupted cylinder in *Dichopsis* (*Madhuca* Baehni) *obovata* C. B. Clarke, *Mimusops commersonii* Engl., *M. elengi* Linn. (Fig. 202 B). About 6, additional, medullary bundles within the cylinder noted in the same species of *Dichopsis*, '*Illipe*' and *Manilkara* and a single, medullary bundle in *Mimusops*. **Laticiferous sacs** (see also 'Axis') present throughout the family, usually accompanying the vascular bundles of the veins but sometimes embedded in the mesophyll, e.g. in species of *Amorphospermum* and *Chrysophyllum*. **Crystals** either solitary, clustered, or in the form of crystal-sand; their nature and distribution sometimes valuable for the identification of species. Crystal-sand sometimes present in the laticiferous elements.

AXIS

YOUNG STEM (Fig. 202 J–K)

Cork arising in the sub-epidermis or outer part of the cortex in species of *Argania*, *Bumelia*, *Chrysophyllum*, *Manilkara* (syn. *Achras*), *Mimusops*, *Pouteria*. **Pericycle** generally containing isolated strands of sclerenchyma which are sometimes arc-shaped, but a continuous ring seen in a few species. Secondary phloem usually containing fibres. **Xylem** forming a continuous cylinder traversed by narrow rays; vessels often in radial rows with small, crowded, lateral pits and mostly simple perforations, occasional scalariform plates also recorded (see 'Wood'); ground tissue, in the species examined at Kew, composed of fibres with very thick walls. **Secretory cells** with unidentified contents, abundant in the cortex, phloem, medullary rays, and pith of nearly all of the species examined at Kew, but absent from the phloem in *Bumelia*. Longitudinally arranged rows of **laticiferous sacs** generally situated in the cortex, phloem, and pith, provide one of the most characteristic features for most members of the family. Individual sacs varying in length and diameter; always filled with refractive material (see 'Economic Uses', p. 879). Full particulars concerning the development of the laticiferous system in *Manilkara zapotilla* (Jacq.) Gilly (syn. *Achras sapota* Linn.) recorded by Karling (1220). Solitary **crystals** always present and often abundant in the cortex of all of the species examined at Kew; sometimes occurring in the

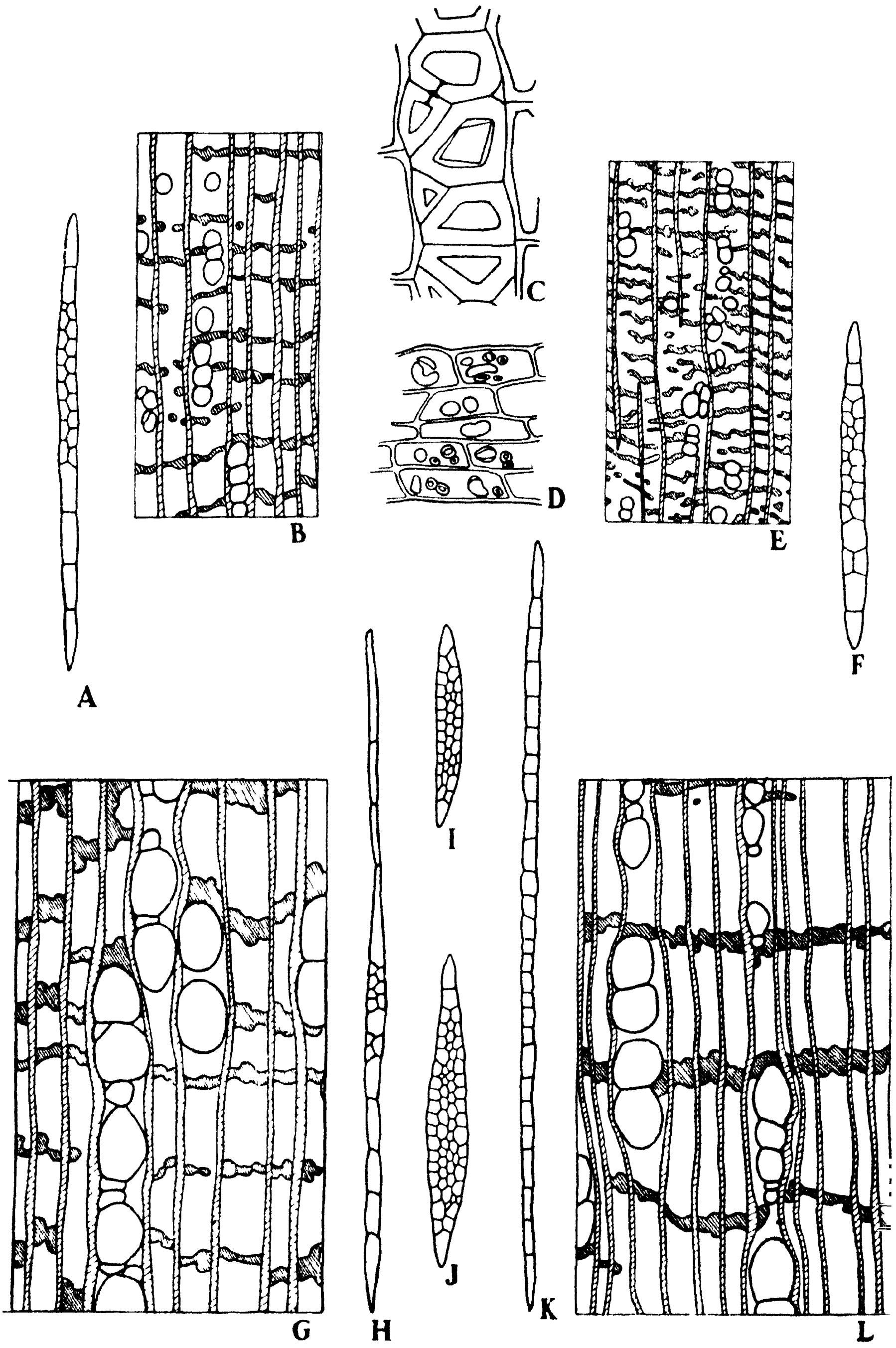


FIG. 201. *SAPOTACEAE*

A, *Palaquium maingayi* (C. B. Clarke) King et Gamble. B, *Pouteria standleyana* (Pittier) Baehni (syn. *Labatia standleyana* Pittier). C, *Sarcosperma paniculatum* (King) Stapf et King. Angular fibre walls (transverse section) × 300. D, *Chrysophyllum cainito* Linn. Vessel-ray pitting × 150. E, *Pachystela argentea* Chev. F, *Mimusops heckelii* Hutch. et Dalz. G, *M. heckelii* Hutch. et Dalz. H, *Pouteria pentasperma* (Standley) Baehni (syn. *Lucuma pentasperma* Standley). I, *Bumelia obtusifolia* R. et Sch. J, *Sersalisia* sp. K, *Madhuca malaccensis* (C. B. Clarke) H. J. Lam. L, *Pouteria egregia* Sandwith.

phloem as well in *Argania*, *Manilkara* (syn. *Achras*) and *Mimusops*, and in the pith in species of *Madhuca*, *Pouteria*, *Sideroxylon* (syn. *Mastichodendron* Baehni). Solitary **crystals** in chambered fibres accompany the other sclerenchymatous elements of the phloem. Cluster crystals also noted in the cortex in species of *Madhuca*, *Mimusops*, *Pouteria*, *Sideroxylon* (syn. *Mastichodendron* Baehni) and in the pith of *Madhuca*, *Pouteria*, *Sideroxylon* (syn. *Mastichodendron* Baehni).

WOOD (Fig. 201)

Vessels commonly medium-sized (100–200 μ mean tangential diameter), small (less than 100 μ) in some species of *Achras*, *Argania*, *Chrysophyllum*, *Manilkara*, *Mastichodendron*, *Mimusops*, *Niemeyera*, and *Pouteria*, and less than 50 μ in some species of *Bumelia*, *Northiopsis*, and *Pouteria*, large (slightly more than 200 μ) in some species of *Madhuca*, *Palaquium*, and *Planchonella*; multiples of 2–3 cells common in all the species and often of 4 or more cells, with the multiples and solitary vessels characteristically grouped loosely together to form a radial or oblique pattern; this pattern most marked and almost flame-like in *Bumelia* (1858), *Niemeyera*, and *Pouteria* (pro parte), least pronounced in, or lacking from, some species of *Chrysophyllum*, *Dipholis*, *Madhuca*, *Malacantha*, and *Pouteria*; the number of solitary vessels and groups very variable and often difficult to determine owing to grouping, typically less than 20 per sq. mm. and not uncommonly less than 5 per sq. mm., e.g. in some species of *Chrysophyllum*, *Madhuca*, *Mastichodendron*, *Omphalocarpum*, *Palaquium*, *Pouteria*, and *Sarcosperma*. According to Record (1851, 1858) the early wood vessels in *Bumelia* are sometimes in narrow concentric bands (semi-ring-porous?). Record (1858) refers to fine spirals in at least some of the vessels in *Bumelia* and *Pouteria*. Perforations exclusively simple in all the material examined; Solereder refers to accompanying scalariform plates with 1–7 bars in *Lucuma* (*Pouteria* Baehni) *cainito* A. DC. and *Chrysophyllum lucumifolium* Griseb. Pearson and Brown (1679) and Record and Mell (1894) refer, in their descriptions of the family, to the perforations as 'simple or scalariform, or both', but do not record scalariform plates in any of their species descriptions. Intervascular pitting alternate, sometimes 'subalternate' according to Record (1858), usually small, but occasionally moderately large. Record and Mell (1894) refer to the pitting in '*Pradosia* (*Chrysophyllum* Baehni) *latescens* (Vell.) Radlk.' as exceedingly small and numerous; pitting to ray and wood parenchyma typically including many large, simple pits, round or elongated and occasionally kidney-shaped (Fig. 201 D). Tyloses commonly present and often abundant; commonly thick-walled and pitted and sometimes sclerotic, e.g. according to Record (1858), in *Bumelia*, *Chrysophyllum*, and *Pouteria*; with characteristic flat walls across the lumina at right angles to the longitudinal vessel walls; tyloses occasionally containing crystals, e.g. in *Chrysophyllum africanum* A. DC. Solereder refers to the presence of calcium carbonate in the vessels of '*Chrysophyllum grisebachii* Mez'. Silica reported (794) in some species of *Chrysophyllum* and *Madhuca*. Mean member length 0·3–1·6 (mostly 0·5–0·7) mm. **Parenchyma** typically apotracheal only, in numerous, narrow bands and often with some scattered cells. Bands usually 1–2 cells wide (Fig. 201 B and E), rather wider in some species of *Argania*, *Manilkara*, *Mastichodendron*, *Mimusops*, and *Pouteria* (Fig. 201 G and L); mostly as scattered cells or short, irregular lines in *Dipholis* and *Niemeyera*; bands tending locally to end blindly and form long, narrow wings from the vessel groups in *Pouteria egregia* Sandwith. Cells often with dark gummy contents; with numerous chambered crystals of calcium oxalate in some species, e.g. of *Butyrospermum*, *Manilkara*, *Mastichodendron*, *Mimusops*, *Northiopsis*, and *Palaquium*. Milanez (1519) gives a detailed and illustrated description of the types of crystal occurring in '*Manilkara huberi* Ducke'. With crystal-sand in *Bumelia obtusifolia* R. et Sch. and, according to Janssonius (1154), in some samples of *Chrysophyllum roxburghii* G. Don, '*Palaquium javense* Burck', and *Sideroxylon* (*Mastichodendron* Baehni) *nitidum* Blume. Silica reported (194, 794, 1154) in some species of *Madhuca*, *Mastichodendron*, *Palaquium*, and *Payena*. Sometimes very thick-walled, e.g. in '*Diploknema oligomera* H. J. L.'. Strands commonly of up to 8 cells. **Rays** typically 2–3 cells wide, but ranging from wholly uniseriate or only occasionally biseriate in *Madhuca*, *Payena* p.p., and *Pouteria* p.p. to 4–5 cells wide in some species of *Bumelia*, *Chrysophyllum*, *Mastichodendron*, *Mimusops*, and *Pouteria*; commonly more than 1 mm. high; uniseriates usually numerous and composed entirely of square to upright cells or with a few procumbent cells, rather few and low in some species; mostly 9–15 rays per mm., occasionally up to 17 per mm., e.g. in *Niemeyera*; typically heterogeneous (Kribs's Type II A and B), with 4 or more marginal rows of upright cells and often with 10 or more, but seldom with as many as 4 rows in some species of *Bumelia*, *Chrysophyllum*, *Dipholis*, *Mastichodendron*, *Mimusops*, and *Pouteria*; rays, where uniseriate only, composed of mixed upright and procumbent cells (Kribs's Type Het. III) or of upright and square cells; the higher rays commonly including 2 or 3 groups of procumbent cells separated by upright cells and with the biseriate parts not much wider tangentially than the uniseriate parts. Commonly containing abundant dark gummy deposits, crystals of calcium oxalate rare; silica reported (194, 794) in some species of *Chrysophyllum*, *Madhuca*, *Mimusops*, *Palaquium*, *Payena*, and *Planchonella*. Solereder, quoting Bargagli-Petrucci, refers to the presence of silica, though not specifically in the rays, in *Bassia* (*Madhuca* Baehni) *crassipes* Pierre. With a tendency to storied arrangement in occasional specimens of some species of *Mimusops*, e.g. *M. heckelii* Hutch. et Dalz., *Sideroxylon*, e.g. *S.* (*Mastichodendron* Lam.) *macranthum* Merrill. **Fibres** typically with rather few, simple pits, more numerous on the radial than on the tangential walls, with small borders in a few species, e.g. of *Chrysophyllum*, *Ganua*, and *Mastichodendron*, and with moderately large and distinctly bordered pits in *Sarcosperma paniculatum* Stapf et King. Janssonius (1154) refers to a few scattered septate fibres in *Chrysophyllum* and *Mastichodendron*, and Marco (1438) to occasional septa in *Sarcosperma paniculatum*. Walls typically thick to very thick, the latter often gelatinous, but moderately thin in some species of *Chrysophyllum*, *Ganua*, *Madhuca*, *Malacantha*, *Mastichodendron*, *Omphalocarpum*, *Palaquium*, and *Pouteria* and in *Mimusops heckelii* Hutch. et Dalz. The walls very angular and the cells occasionally containing crystals in *Sarcosperma* (Fig. 201 C). With large pits to ray cells in *Ganua* (*Madhuca* Baehni) *motleyana* Pierre. Silica reported (794) in some species of *Chrysophyllum* and *Madhuca* and unidentified crystals observed in *Pouteria*. Mean length 0·8–2·4 (mostly 1·0–1·5) mm. **Vasicentric tracheids** commonly present, numerous in

Bumelia, *Madhuca*, and *Pouteria*, and present, mixed with very small vessels and vascular tracheids, in several other genera. **Growth rings.** The development of the ring in *Manilkara* spp. in Java has been investigated by Coster (481). Besson (186) records high percentages of silica in the wood and ash of species of *Mimusops* and *Manilkara.*

ROOT

Laticiferous sacs, arranged in longitudinal rows, present in the cortex and a network of similar elements in the phloem.

TAXONOMIC NOTES

The taxonomy of this family is confused owing to the lack of clear, intergeneric distinctions. Baehni (63) has published, comparatively recently, a preliminary account of his views concerning the general classification of the family, and has amalgamated a number of the genera previously recognized as distinct. Baehni (64) has since published a very detailed account of the greatly enlarged genus *Pouteria.* Lam (1314) has questioned some of the views expressed by Baehni in the first of the above papers, and, in particular, believes that too many genera have been amalgamated, thus making some of them too large. Baehni undertook his investigation mainly in the hope of simplifying the task of identification, which he believes to be the main object of taxonomy. Lam, on the other hand, adopted the more scientific view that taxonomic units are of more fundamental significance than mere conveniences in identification. Then again, Baehni has stated his belief that anatomical features may be ignored in classifying the Sapotaceae, since a satisfactory arrangement can be made without having to examine the microscopical features. Lam again takes the more reasonable view that a system of classification based on as many characters as possible is more likely to be correct than one based exclusively on exomorphic features. In this connexion it is interesting to note the opinion of Record (1858) that 'the author is convinced that a systematic study of the woods would be of great assistance in solving some of the taxonomic problems, but the material now available is insufficient for conclusive results'. Still more recently certain genera of Sapotaceae have been revised by Cronquist (505, 506, 507).

It is clearly outside the scope of this book to include an authoritative opinion concerning such a complex question as the taxonomy of the Sapotaceae. In the present text, the genera mentioned are mostly those recognized by Baehni, except that the ones which Lam considers should still be kept distinct have been treated accordingly. This seems a reasonable course to adopt until a new monograph of the whole family is available. Where individual species have been mentioned it has sometimes been necessary to give the name in common use before Baehni's article was published, since it is undesirable to anticipate Baehni by making new combinations which he has not yet published. Thus, although Baehni states that *Dichopsis* should be merged in *Madhuca*, the name *Dichopsis obovata* C. B. Clarke has been retained in this book because the combination *Madhuca obovata* (C. B. Clarke) Baehni has never yet been published. In order to indicate that a new combination may be made hereafter, the new generic name is given in brackets, thus: *Dichopsis* (*Madhuca* Baehni) *obovata* C. B. Clarke.

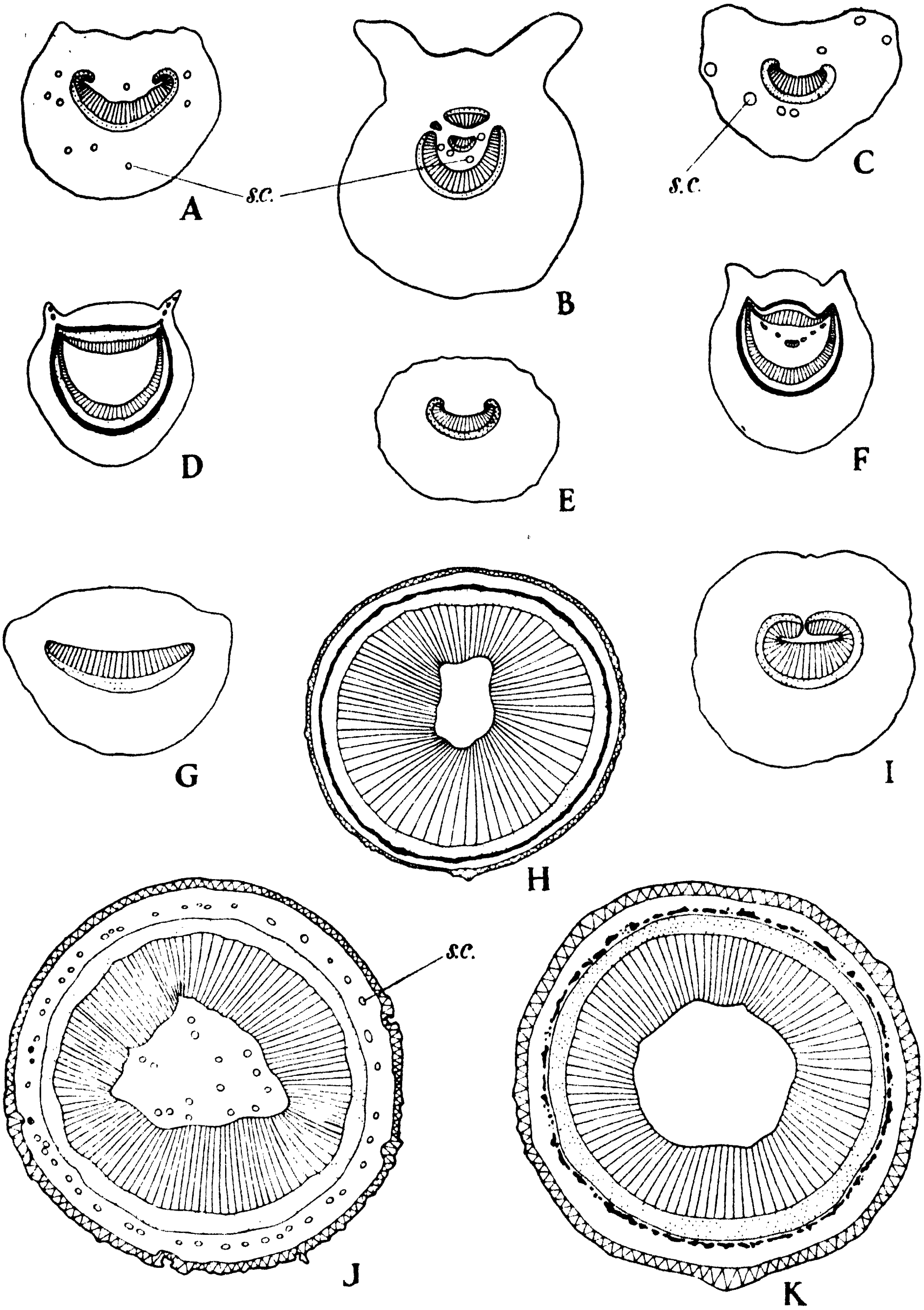


FIG. 202. *SAPOTACEAE*, A–D, F, and J–K; *EBENACEAE*, E and G–I

A, *Bumelia lanuginosa* Pers. Petiole ×18. B, *Mimusops elengi* Linn. Petiole ×19. C, *Argania sideroxylon* Roem. et Schult. Petiole ×50. D, *Calocarpum mammosum* (L.) Pierre (syn. *Lucuma mammosa* (L.) Gaertn.). Petiole ×8. E, *Royena lucida* Linn. Petiole ×19. F, '*Illipe* (*Madhuca* Baehni) *longifolia*'. Petiole ×19. G, *Diospyros virginiana* Linn. Petiole ×15. H, *D. lotus* Linn. Stem ×8. I, *D. embryopteris* Pers. Petiole ×8. J, *Bumelia lanuginosa* Pers. Stem ×19. K, *Chrysophyllum cainito* Linn. Stem ×23.

s.c. Secretory canals or sacs.

Gilly (784) has recently proposed the name *Manilkara* for various species previously included in *Achras* and *Sapota.*

It is interesting to note that Lam has proposed that *Sarcosperma* should form the basis of a distinct family the Sarcospermaceae. Marco (1438) followed up this suggestion by making a study of the structure of the wood of *S. paniculatum* (King) Stapf et King, and found a general agreement in structure between *Sarcosperma* on the one hand and *Chrysophyllum* and *Lucuma* on the other. The wood fibres of *Sarcosperma* differ from those of the Sapotaceae in having conspicuously bordered pits. Pits with small borders have, however, been observed in a few other genera of Sapotaceae (see 'Wood', p. 876) so that the above distinction is not absolute.

ECONOMIC USES

Several edible fruits, well known in tropical countries, are derived from members of this family. These include the Sapodilla (*Manilkara zapotilla* (Jacq.) Gilly (syn. *Achras sapota* Linn. and other species of *Manilkara* from Tropical America); the Star Apple (*Chrysophyllum cainito* Linn.) and the Marmalade Plum (*Lucuma mammosa* Gaertn.) chiefly from the West Indies and Tropical America. The Miraculous Berry of West Africa, which gives a sweet taste to even the sourest foodstuffs, is derived from *Synsepalum dulcifolium* (Schum.) A. DC. Shea Butter is the fat obtained from the seeds of *Butyrospermum parkii* (G. Don) Kotschy which grows in West Africa and the Sudan, whilst in North Africa and Morocco a substitute for olive oil is extracted from the seeds of *Argania sideroxylon* R. et S. Gutta-percha, imported chiefly from the Malay Peninsula, is derived from the latex of *Palaquium gutta* (Hook.) Baill., Forma *genuinum* H. J. Lam, and other forms and varieties of the same species, whilst Balata, a somewhat similar substance from Tropical America, is obtained from *Manilkara bidentata* (A. DC.) A. Chev. and other species of *Manilkara.* The occurrence and formation of gutta-percha in the leaves of *P. gutta* have been fully described from a microscopical standpoint by Varossieau (2322). According to Gilly (784) chewing-gum is prepared from the latex of a group of variable and closely related species of *Manilkara* (syn. *Achras*).

The woods of this family are typically hard, heavy, and durable and are sometimes difficult to season and to work with tools. The most important genera are *Manilkara* and *Mimusops*, which furnish, for example, Makoré or Cherry Mahogany (*Mimusops heckelii* (Pierre) Hutch. et Dalz.) from West Africa, Beefwood or Bulletwood (*Manilkara bidentata* (A. DC.) A. Chev.) from British Guiana, and Massandaruba (*Manilkara huberi* (Ducke) A. Chev.) from Brazil. Many of the other species and genera are used locally for purposes requiring a hard and strong wood, such as heavy construction, tool handles, and wheelwrights' work. The wood of *Palaquium ellipticum* (Dalzell) Engler is in great demand in India, according to Pearson and Brown (1679), for masts and spars.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Amorphospermum, Argania,* Bumelia,* Chrysophyllum,* Delpydora, Labourdonnaisia, Madhuca* (including Bassia (syn. Illipe) and Dichopsis), Manilkara* (syn. Achras), Mastichodendron* (syn. Sideroxylon excluding Calvaria), Mimusops,* Omphalocarpum, Pouteria* (including Lucuma), Sarcosperma, Sideroxylon (syn. Calvaria), Synsepalum.

* Represented in the Kew slide collection.

(ii) For Wood Structure

Argania, Bumelia, Butyrospermum, Chrysophyllum, Dipholis, Ganua, Labramia, Madhuca (including Bassia (syn. Illipe) and Dichopsis), Malacantha, Manilkara (syn. Achras), Mastichodendron (syn. Sideroxylon excluding Calvaria), Mimusops, Niemeyera, Northiopsis, Omphalocarpum, Palaquium, Payena, (Planchonella), Pouteria, Sarcosperma.

LITERATURE

(i) *On General Anatomy*

Baehni **62, 63, 64,** Cronquist **505, 506, 507,** Gilly **784,** Karling **1220,** Kienholz **1236,** Lam **1314,** Varossieau **2322.**

(ii) *On Wood Structure*

Benoist **170,** den Berger **179,** Besson **186,** Bianchi **194,** B.H. For. Dept. **274,** Brown, F. B. H. **282,** Burgerstein **312,** Cooper and Record **461,** Coster **481,** Demougeot **563,** Dixon **592,** Foxworthy **705,** Giordano **786, 787,** Gonggrijp **794,** Howard **1088,** Janssonius **1154,** Jayawardana **1159,** Jentsch **1172, 1177,** Jolly **1188,** Jones **1191,** Kanehira **1206, 1209,** Kramer **1275,** Kribs **1283,** Lecomte **1334,** Link **1377,** Marco **1438,** Martin-Levigne **1450,** Méniaud **1492,** Milanez **1519,** Pearson and Brown **1679,** Pfeiffer, J. P. H. **1713,** Record **1780, 1781, 1783, 1794, 1809, 1812, 1843, 1851, 1858,** Record and Hess **1886,** Record and Mell **1894,** Riera **1937,** Scott **2075,** Stone **2202, 2207.**

184. EBENACEAE

(Fig. 202 on p. 878; Fig. 203 on p. 882; Fig. 204 on p. 884)

SUMMARY

(i) GENERAL

A mainly tropical and sub-tropical family of trees and shrubs. The **hairs** are mostly unicellular, occasionally in tufts, sometimes with 2 arms. Glandular hairs consisting of a curved, uniseriate stalk and a head composed of a few cells also occur. The ranunculaceous **stomata** are usually confined to the lower surface of the leaf. Sclerosed cells are present in the **mesophyll** of numerous species of *Diospyros*. The axis does not provide any noteworthy features apart from those of the secondary xylem. The presence of large solitary **crystals** in various parts of the plant, notably in the mesophyll of the leaf, is characteristic of many members of the family. Clustered crystals also occur.

Various authors, including Busch (323), Solereder (2165), and Griffioen (821), have examined the dark-coloured material which is secreted in the leaf, stem, and mature wood in various members of the family, including species of *Diospyros*, *Euclea*, *Maba*, *Royena*, *Tetraclis*. It probably occurs generally throughout the family. This secretion becomes dark reddish-violet when treated with a 1 per cent. solution of caustic potash or with eau de Javelle. It forms a yellowish solution in alcohol, fluoresces blue by reflected, and yellowish by transmitted, light. Other colour reactions have been recorded by Busch, and the nature and mode of formation of the material, especially in ebony woods, have been discussed by Griffioen. The colour reactions shown by this material serve to differentiate true ebony from substitutes (see also under 'Wood'). The genus *Brachynema* differs so much from other members of the family that it is described separately on p. 885.

(ii) WOOD

Vessels small to medium-sized, with numerous multiples of 2 or 3 cells and sometimes with longer multiples of 4 or more cells giving a radial or oblique pattern, perforations simple, intervascular pitting alternate and small, pits to parenchyma similar; members usually of medium length, occasionally moderately or very short. **Parenchyma** typically in numerous uniseriate apotracheal bands, often with some scattered cells and narrow vasicentric sheaths in addition, occasionally storied. **Rays** usually up to 2 cells wide or wholly uniseriate, heterogeneous, sometimes markedly so, sometimes storied. **Fibres** with small bordered pits, sometimes with conspicuous contents; usually of medium length, occasionally moderately short.

LEAF

Usually dorsiventral, but tending to be isobilateral in certain species of *Diospyros*, *Euclea*, *Royena*. **Hairs** include the following kinds. (i) Long or short unicellular trichomes, sometimes arranged in tufts or clusters, lying at right angles or obliquely to the leaf surface. (ii) Unicellular, with 2 equal or unequal arms in species of *Diospyros*. (iii) Small, club-shaped, glandular hairs with curved, uniseriate stalks recorded in *Diospyros* (Fig. 203 C) and *Royena*, but much more frequent in some species than in others and chiefly situated on the lower surface; said to be particularly numerous on young leaves. (iv) A rusty-brown, deciduous tomentum of hairs, each consisting of a short unicellular stalk bearing a variously shaped but somewhat shield-like distal part composed of 6–10 or more radiating, often warty cells with thin walls and brown tanniferous contents, recorded by Solereder (2165) in *Diospyros hildebrandtii* Gürke. Infrequent, sunken **extra-floral nectaries** noted by Busch (323) in 54 species of *Diospyros*. **Cuticle** varying in thickness; sometimes striated. **Epidermis** composed of cells differing considerably in size according to the species and having sinuous or, more rarely, straight anticlinal walls; sometimes with very much thickened or, in certain species of *Diospyros* and *Maba*, coronulate papillae on the lower surface (Fig. 203 A–B). **Stomata** usually ranunculaceous, but subsidiary cells differentiated in certain species of *Diospyros* according to Busch (323); nearly always with a rather wide front cavity; usually confined to the lower surface, but a few recorded on the upper side as well, e.g. in *Diospyros virginiana* Linn. **Hypoderm** generally absent, but 2 layers towards both surfaces recorded by Guillaumin (843) in *Oncotheca*, and a sclerosed hypoderm beneath the lower epidermis by Busch (323) in *Diospyros oleifolia* Wall. **Mesophyll.** Spongy tissue dense in some species, but with abundant intercellular spaces in others. Yellow, sclerosed, pitted cells, either solitary or in clusters, and sometimes slightly branched, recorded by Solereder and Busch (323) in the mesophyll and particularly the palisade layers of numerous species of *Diospyros*. Stone cells present in the parenchymatous portions of the veins of the petiole in species of *Diospyros*, *Euclea*, *Maba*, and *Oncotheca*. Vascular bundles of **the veins,** in some species of *Diospyros*, accompanied by well-developed sclerenchyma; small veins vertically transcurrent on one or both sides by parenchyma or collenchyma in most species of *Diospyros*, rarely by sclerenchyma, e.g. in *D. oleifolia* Wall. **Petiole** (Fig. 202 E, G, I) of *Diospyros* and *Royena*, in transverse sections through the distal end, exhibiting a solitary, crescentic, vascular strand, the shape of the latter varying in different species from open and slightly concave to deep with strongly incurved ends. Petiole of *Oncotheca* figured by Guillaumin (843) as showing a slightly interrupted, crescentic, median strand with the ends very much incurved and almost in contact with one another, a small accessory strand being present within the arc and others towards the wings. **Secretory cells,** similar to those in the stem, abundant in the cortical region and sometimes the phloem of the petiole of species of *Diospyros* and *Royena* examined at Kew. **Crystals** of various sizes usually abundant, mostly solitary, or, more rarely, clustered. Specially big solitary crystals situated in enlarged mesophyll cells recorded in many species of *Diospyros*, *Maba*, *Royena*, and occasionally appearing as transparent dots in the leaf. Large crystals extend across the full width of the mesophyll in species with thin leaves. Crystals said by Busch (323) to be absent from *Diospyros argentea* Griff. and *D. macrophylla* Bl. Unidentified crystalline material also noted by Busch in herbarium specimens of a number of species of *Diospyros*. The same author also observed oily and fatty material, as well as other chemical substances, in the leaf. For detailed descriptions of the leaf of a considerable number of species of *Diospyros* see Busch's (323) thesis.

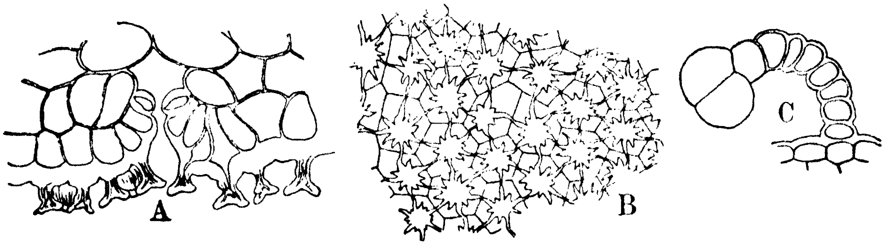


FIG. 203. *EBENACEAE*
A–B, Papillose epidermis of the lower side of the leaf in *Diospyros discolor* Willd.; A in a transverse section; B, in surface-view. C, Glandular hair of *Diospyros kaki* L.f.—By Solereder.

AXIS

YOUNG STEM (Fig. 202 H)

Cork arising immediately below the epidermis in *Diospyros*, *Maba*, *Tetraclis*; pericyclic in *Euclea* and *Royena*. A sclerotic phelloderm formed internally in *Euclea* and *Royena*. Sclerosed idioblasts or large stone cells recorded by Guillaumin (843) in the narrow cortex of *Oncotheca*. **Pericycle** usually containing a composite and continuous ring of sclerenchyma in *Diospyros*, but the width of the ring and its degree of continuity vary in different species; isolated strands of fibres sometimes occur in this region in *Euclea*, *Oncotheca*, and *Royena*. Secondary **phloem** usually devoid of fibres but stone cells present in certain species of *Diospyros*, e.g. *D. embryopteris* Pers. and a few sporadic fibres in *Oncotheca*. **Xylem,** at least in *Diospyros*, *Oncotheca*, and *Royena*, consisting of a continuous cylinder traversed by narrow rays; vessels solitary or in short radial clusters and provided with simple perforations. **Pith** of *Diospyros embryopteris* including groups of large stone cells, but none seen in other species. A few fibres, either solitary or in strands of 2–4, recorded by Guillaumin (843) in *Oncotheca*. **Secretory cells** with unidentified but probably tanniniferous contents abundant in the cortex, phloem, rays, and pith of most of the species of *Diospyros* examined at Kew. Similar cells also present in the cortex and pith of *Royena lucida* Linn., but none seen in the phloem or rays of this species. Solitary **crystals** generally present and often abundant in the unlignified tissues; very small ones recorded in the cortex of *Oncotheca*.

WOOD (Fig. 204)

Vessels typically small (less than 100 μ mean tangential diameter) and sometimes very small (25–50 μ), e.g. in *Royena lucida* L., but medium-sized (100–200 μ) in some species of *Diospyros*, e.g. *D. brachiata* King et Gamble, *D. ehretioides* Wall., and *D. maingayi* (Hiern.) Bakh.; solitary and in multiples of 2 or 3 cells, with multiples of 4 or more cells moderately common, in some species of *Diospyros* and *Maba* and pronounced in *Euclea* (Fig. 204 C) and *Royena*, and occasionally forming a vague radial or oblique pattern, e.g. in *Diospyros embryopteris* Pers. (Fig. 204 H), *D. malaccensis* Bakh., and *D. tristis* K. et G.; commonly 2–4 per sq. mm. but more numerous (up to 15 per mm.) in some species of *Diospyros*, e.g. *D. burmanica* Kurz., and *Royena*; with a slight tendency to ring-porousness in *Diospyros virginiana* L. Perforations simple. Intervascular pitting alternate, and small to minute, with marked striations due to coalescent apertures in some species of *Euclea* and *Maba*; pits to ray and wood parenchyma similar to the intervascular pitting. Sometimes with abundant solid deposits, particularly in species with black heartwood; tyloses occasionally present, e.g. in *Diospyros moonii* Thw. Mean member length 0·2–0·5 mm. **Parenchyma** predominantly apotracheal, in numerous uniseriate lines varying from irregular and short to moderately straight and continuous, the latter, e.g. in *Diospyros maingayi*, *D. polyalthoides* Korth., *D. sanza-minika* A. Chev. (Fig. 204 F), and *D. tristis* K. et G., with some scattered cells (diffuse); sometimes with distinct vasicentric sheaths round the vessels, e.g. in *Diospyros ehretioides*, *D. glandulosa* Lace, *D. undulata*, and *Euclea lanceolata* E. Mey. (Fig. 204 C). Cells often filled with gummy contents, and with chambered crystals in some species of *Diospyros* and *Maba*. Strands typically of 4 cells in the apotracheal parenchyma (strands of 2 cells common in *D. glandulosa*), strands of vasicentric parenchyma, when present, usually of 8 cells. Storied in *Diospyros glandulosa*, *D. kaki* L., and *D. virginiana*. **Rays** typically 1–2 cells wide, but up to 3 or 4 cells in a few species of *Diospyros*, e.g. in *D. glandulosa* and *D. virginiana*, and in *Euclea lanceolata* E. Mey.; wholly uniseriate or with only occasional biseriate parts in most species of *Diospyros* (Fig. 204 B and E) and *Maba*; 2 cells wide in some other species, e.g. *D. ehretioides*, *D. virginianum*, and *M. verae-crucis* Standl.; less than 1 mm. high; uniseriates numerous and typically composed of square to upright and procumbent cells, but of procumbent cells only in *D. virginiana*; 10–17 rays per mm.; typically heterogeneous (Kribs's Types II B and III), the multiseriate rays commonly with 4 or more marginal rows of upright cells

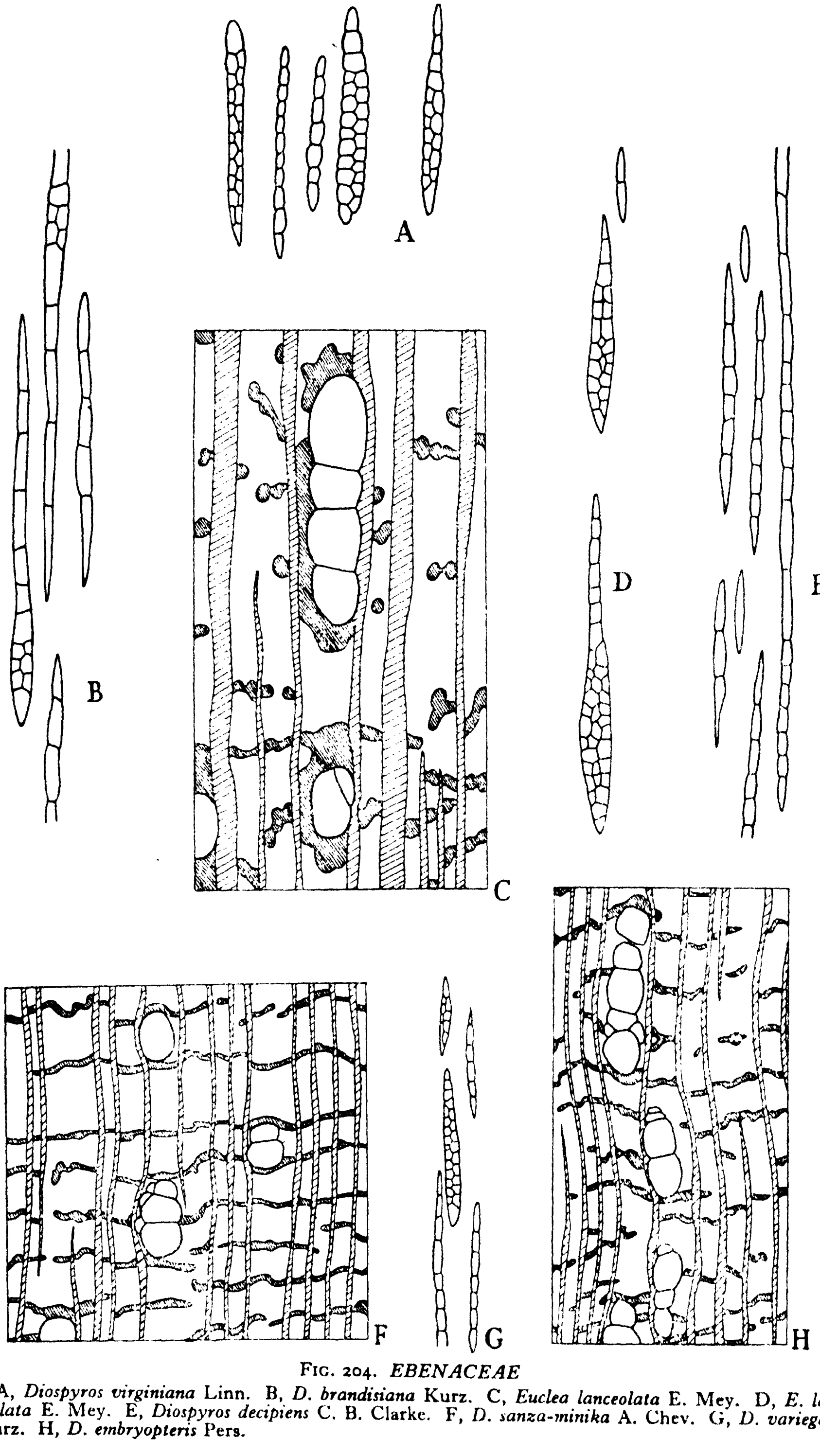


FIG. 204. *EBENACEAE*

A, *Diospyros virginiana* Linn. B, *D. brandisiana* Kurz. C, *Euclea lanceolata* E. Mey. D, *E. lanceolata* E. Mey. E, *Diospyros decipiens* C. B. Clarke. F, *D. sanza-minika* A. Chev. G, *D. variegat* Kurz. H, *D. embryopteris* Pers.

and sometimes with 2 or more multiseriate parts per ray, particularly in species with rays that are intermediate between exclusively uniseriate and multiseriate; procumbent cells of the uniseriate rays often high axially and not clearly distinguished from square cells in tangential sections; homogeneous (Kribs's Type I) in *D. virginiana*; sometimes with numerous crystals, either singly in all the cells or, occasionally, with 3 or 4 chambered crystals in the procumbent cells; usually with dark gummy contents; sometimes with marked intercellular spaces; storied in *Diospyros glandulosa*, *D. kaki*, *D. lotus* L. (1209), *D. morrisiana* Hance (1206), *D. sasakii* Hay. (1206), and *D. virginiana*. **Fibres** with small bordered pits more numerous on the radial than the tangential walls, the borders often very small, but moderately large and distinct in some species of *Diospyros*. Walls moderately to very thick. Occasionally with plugs of solid material in the lumina, e.g. in *Euclea lanceolata* and *Maba cooperi* Hutch. et Dalz., and sometimes completely filled with dark matter, e.g. in *Diospyros ebenum* Koenig and *D. quaesita* Thw.; occasionally, according to Janssonius (1154) containing crystals in *D. truncata* Zoll. et Mor. Mean length 0·75–1·4 mm. Griffioen (821) has investigated the colouring matter in the heartwood of some ebonies. The red-brown matter in the ray and wood parenchyma cells differs from the black contents of the vessels and fibres; the latter has the properties characteristic of humic acids and the amount of lignin in the walls of these cells is reduced.

THE ANOMALOUS GENUS BRACHYNEMA

The following features have been recorded by Solereder concerning the monotypic Brazilian genus *Brachynema*.

Leaf

Dorsiventral. **Epidermis** consisting of cells with fairly straight anticlinal walls. **Stomata** confined to the lower surface; surrounded by 3 subsidiary cells. Vascular bundles of the **veins** embedded in a sclerenchymatous ring, and accompanied by numerous cells containing relatively small solitary crystals surrounded by sclerotic thickenings (see also 'Stem').

Axis

Outer part of the primary **cortex** containing vertical rows of cells with wide lumina filled with blood-red contents; inner part including a broad ring of stone cells. **Pericycle** provided with isolated strands of fibres. **Pith** including transverse plates of stone cells. **Crystals** in special cells, similar to those accompanying the vascular bundles of the veins, occur near the pericyclic fibres and stone cells.

Taxonomic Notes

In the past the taxonomic position of *Oncotheca* has been uncertain. Guillaumin (843) has investigated this matter from the anatomical standpoint, and concluded that the evidence favours its retention in the Ebenaceae, the similarity to *Royena* being especially well marked. He suggests, however, that *Oncotheca* ought to be placed in a distinct tribe.

There is a close general similarity between the woods of the Sapotaceae and those of the Ebenaceae (cf. Figs. 201 and 204).

ECONOMIC USES

Only a few of the species of *Diospyros* have a completely black heartwood and so produce true Ebony, of which the principal sources are *D. ebenum* Koen. (mostly from Ceylon) and *D. melanoxylon* Roxb. from India. Among African species reputed to produce Ebony are *D. crassiflora* Hiern., *D. mespiliformis* Hochst., and *D. piscatorius* Gürke. Other species have a streaked or mottled heartwood that produces highly ornamental timber, e.g. *D. macassar* A. Chev., Macassar Ebony, *D. marmorata* Park., Andaman Marblewood or Zebrawood, and the now rare *D. quaesita* Thw., Caromandel or Calamander wood, from Ceylon. Persimmon, *D. virginianum* Linn., is widely used for weaving shuttles and is the standard wood for the heads of golf clubs. Some of the other species without a distinctive heartwood are valued locally as poles, for example, for the mining industry in West Africa.

A gum is obtained in India, Burma, and Ceylon from the pulp of the red fruits of *Diospyros embryopteris* Pers., whilst the leaves of the same species are said to have been used for wrapping cigarettes. The Japanese Persimmon or Date Plum is the edible fruit of *D. kaki* Linn. The bark of *D. multiflora* Blanco, which contains a substance used in the preparation of an arrow poison, is characterized, according to Busch (323), by the following features. Bark 8 mm. thick; outer part composed of several layers of cork appearing dark coloured to the naked eye, about 1 mm. thick and composed of thin-walled cells with dark-brown contents; phelloderm consisting of several layers of radially arranged, sclerosed cells; primary cortex also largely composed of sclerosed cells and not clearly differentiated from the pericyclic zone initially characterized by a composite, continuous ring of sclerenchyma; secondary phloem containing sclerosed rod and stone cells but no typical fibres, and traversed by uniseriate but distally broadened rays; large and small solitary crystals in the primary cortex and secondary phloem, mostly situated in chambered cells in the last tissue.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Brachynema, Diospyros,* Euclea, Maba, Oncotheca, Royena,* Tetraclis.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Diospyros, Euclea, Maba, Royena.

LITERATURE

(i) *On General Anatomy*

Busch **323**, Griffioen **821**, Guillaumin **843**, Holm **1037**, Solereder **2165**.

(ii) *On Wood Structure*

Baker **104**, Benoist **170**, Besson **186**, Brown, F. B. H. **282**, Brown, H. P. and Panshin **288**, **289**, Burgerstein **310**, Chowdhury **411**, Desch **574**, Foxworthy **705**, Griffioen **821**, Gupta **849**, Howard **1088**, Janssonius **1154**, Jones **1191**, Kanehira **1206**, **1209**, **1213**, Kribs **1283**, Masao **1453**, Méniaud **1492**, Pearson and Brown **1679**, Record **1781**, **1783**, **1809**, **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**, Tang **2230**, Williams **2430**, Yamabayashi **2478**.

185. STYRACACEAE

(FIG. 205 on p. 888; FIG. 208 on p. 898)

SUMMARY

(i) GENERAL

The family occurs in relatively warm parts of the world, such as the Mediterranean region, eastern Asia, the Malay Archipelago and parts of North and South America; 1 genus occurs in tropical Africa. The leaves of the trees and shrubs belonging to the family are often characterized by an indumentum of stellate or scale-like **hairs.** The Storax and Gum Benzoin obtained respectively from *Styrax officinale* L. and *S. benzoin* Dry. are secreted chiefly in pathological intercellular spaces of the phloem, rays, and wood of the axis. The **cork** generally originates in the pericyclic region of the stem.

(ii) WOOD

Vessels small, perforation plates scalariform, intervascular pitting usually scalariform or opposite, pits to ray cells small and round, members usually of medium length to moderately long. **Parenchyma** apotracheal, diffuse, and in regular, uniseriate lines. **Rays** usually up to 2–4 cells wide, but sometimes up to 6 cells, markedly heterogeneous. **Fibres** with bordered pits, of medium length to moderately long.

LEAF

Dorsiventral. Stellate **hairs,** with thick walls to the ray-cells and sometimes resembling small scales, recorded by Solereder in *Halesia*, *Pamphilia*, *Styrax*, and probably occurring in other genera as well. Leaf of *Styrax heterotricha* Perk. bearing scattered, brown scales, with a tomentum of very small stellate hairs beneath them. Arms of the stellate hairs especially long in *Styrax foveolaria* Perk. Cluster hairs also recorded, e.g. in *Pamphilia styraciflua* A. DC. **Stomata** confined to the lower surface; ranunculaceous. Vascular bundles of the smaller **veins** accompanied by sclerenchyma; vertically transcurrent above by cells with wide lumina in *Styrax camporum* Pohl. and *Pamphilia styraciflua* A. DC. **Petiole,** in transverse sections through the distal end, with a median, cylindrical, vascular strand, flattened towards the adaxial surface and often accompanied by accessory strands in the wings in *Halesia carolina* Linn. (Fig. 205 C), *H. diptera* Ell., *H. monticola* Sarg., and *Pterostyrax hispida* Sieb. et Zucc. (Fig. 205 A); with a shallow crescentic strand with incurved ends in *Styrax hemsleyana* Diels (Fig. 205 B); with a shallow crescentic strand accompanied by 2 smaller accessory bundles towards the adaxial surface and by a small compound bundle between the ends in *S. officinale* Linn. One subsidiary strand in each of the wings also present in *S. hemsleyana* and *S. officinale*. Both solitary and clustered **crystals** reported to occur, especially around the vascular bundles, in species of *Halesia* and *Styrax*.

AXIS

YOUNG STEM (Fig. 205 E)

Cork arising in the pericycle in *Alniphyllum*, *Halesia* (Fig. 205 E), *Pamphilia*,

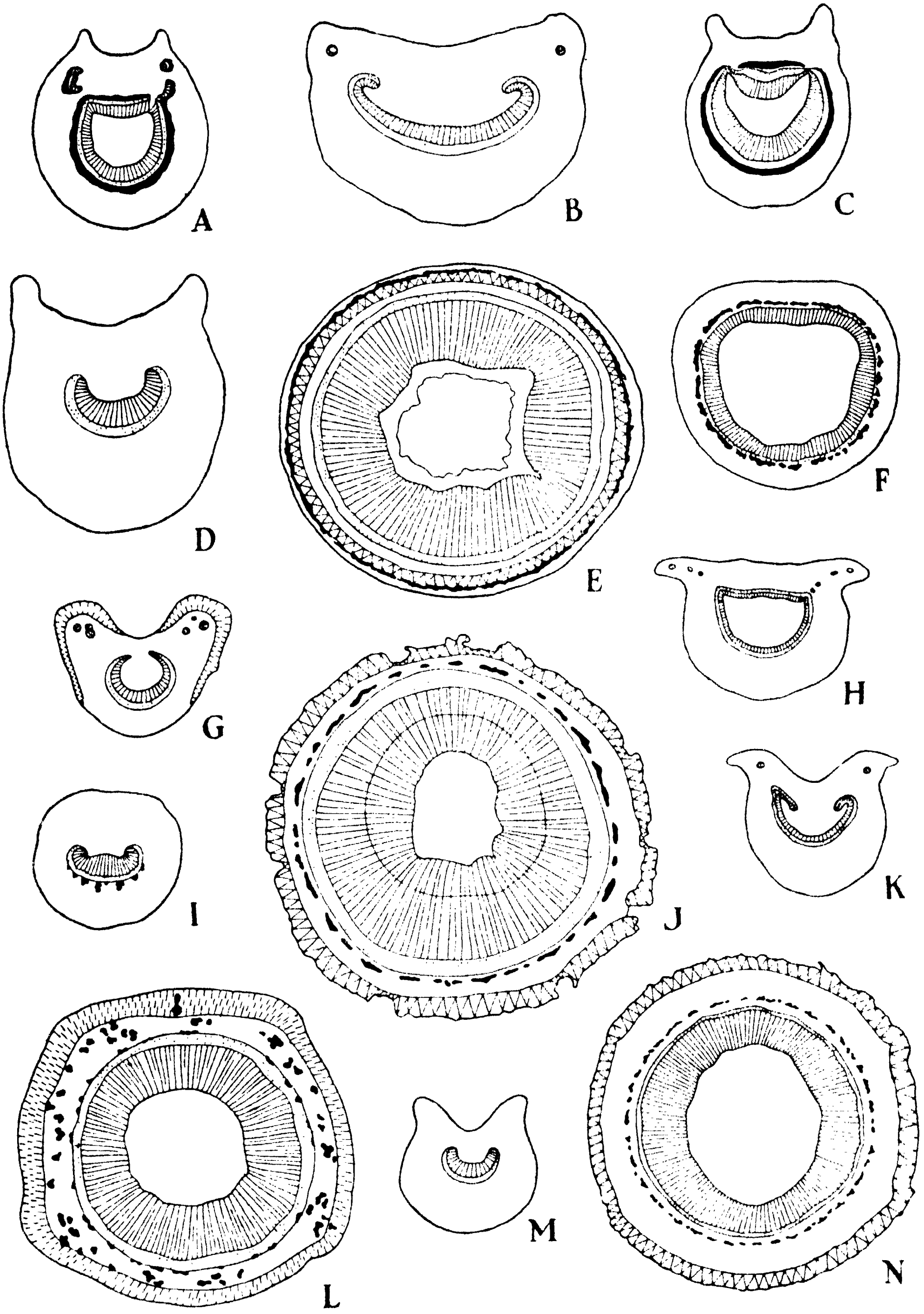


FIG. 205. *STYRACACEAE*, A–C and E; *SYMPLOCACEAE*, D and J; *OLEACEAE*, F–I and K–N

A, *Pterostyrax hispida* S. et Z. Petiole × 15. B, *Styrax hemsleyana* Diels. Petiole × 19. C, *Halesia carolina* Linn. Petiole × 18. D, *Symplocos paniculata* Wall. Petiole × 20. E, *Halesia carolina* Linn. Stem × 19. F, *Fraxinus excelsior* Linn. Petiole × 11. G, *Jasminum pubigerum* D. Don. Petiole × 13. H, *Chionanthus virginica* Linn. Petiole × 13. I, *Phillyrea angustifolia* Linn. Petiole × 19. J, *Symplocos paniculata* Wall. Stem × 20. K, *Syringa villosa* Vahl. Petiole × 13. L, *Jasminum humile* Linn. Stem × 13. M, *Ligustrum vulgare* Linn. Petiole × 13. N, *Syringa villosa* Vahl. Stem × 13.

Styrax. **Pericycle** including a closed or slightly interrupted ring of sclerenchyma in *Halesia*, *Pamphilia*, *Styrax*; pericyclic sclerenchyma described by Perkins (1689) as forming a closed ring in *Bruinsmea* and *Pterostyrax*, and as consisting of solitary fibres in *Alniphyllum*. Secondary **phloem** including sclerenchymatous elements in species of *Pamphilia* and *Styrax*. **Xylem** forming a continuous cylinder traversed by narrow rays. Vessels with scalariform perforation plates. **Pith** septate in *Halesia*. Intercellular **secretory cavities** in the phloem, rays, and wood of *Styrax benzoin* Dryand. arise pathologically and contain the balsamic resin benzoin (see 'Economic Uses'). **Secretory cells** with unidentified contents noted in the phloem and sometimes the medull .ry rays in species of *Halesia* examined at Kew. **Crystals** of calcium oxalate present in the unlignified tissues of species of *Halesia*, *Pterostyrax*, and *Styrax*; more frequently solitary than clustered, especially in the phloem.

WOOD (Fig. 208 A–C)

Vessels small (less than 50 μ mean tangential diameter) to medium-sized (100–200 μ); solitary and in short multiples, multiples of 4 cells moderately common in a few species and with a radial pattern in *Alniphyllum*; usually 10–20 per sq. mm. but more numerous in *Halesia* and *Huodendron* and fewer than 5 per sq. mm. in *Bruinsmea*; with a tendency to be ring-porous in some species of *Halesia* and *Styrax*. Perforation plates typically scalariform, the bars fewer than 20 and rather fine, but with some simple perforations in *Bruinsmea*. Intervascular pitting typically scalariform or opposite, but alternate in *Bruinsmea* and some species of *Styrax*; pits to ray and wood parenchyma usually small and round. Solid deposits rare, tyloses not observed or reported. Mean vessel member length typically 0·7–1·0 mm., but reported (1206) to be about 1·65 mm. in *Alniphyllum*. **Parenchyma** apotracheal, diffuse and in short, irregular, uniseriate lines (Fig. 208 B); with chambered crystals in *Bruinsmea*. Strands usually of 8 cells. **Rays** usually described as of 2 sizes; the larger usually 2–4 cells wide, but up to 5 or 6 cells in some species of *Bruinsmea*, *Huodendron*, and *Styrax*; more than 1 mm. high in *Alniphyllum*, *Bruinsmea*, and *Huodendron*; uniseriates numerous and composed of square to upright cells; 9–15 rays per mm.; heterogeneous (Kribs's Types II A and B), typically with 4–10 marginal rows of square or upright cells and commonly with more than 10 rows in *Alniphyllum*, *Huodendron*, and *Styrax*. Cells often with gummy contents; crystals not observed. **Fibres** with small bordered pits that tend to be more numerous on the radial than on the tangential walls. Walls of medium thickness. Mean length 1·1–1·8 mm. **Intercellular canals** of the vertical traumatic type reported in *Styrax* (179, 1851).

ECONOMIC USES

Benzoin or Gum Benzoin, a balsamic resin used for various medicinal purposes, is obtained from *Styrax benzoin* Dryand., grown chiefly in Sumatra. The secretion of the resin is stimulated by cutting into the trunk to the depth of the cambium. Various other kinds of benzoin, likewise obtained from species of *Styrax*, are also on the market. Specimens of West African 'Garlic Bark', said to be derived from branches of *Afrostyrax lepidophylla* Mildbr.

20–25 cm. in diameter, have been described by Mildbraed (1533) as follows. External surface of bark consisting of grey cork, and covered with warty flakes. Transverse sections exhibit, on passing from the external to the internal surface, several layers of regularly arranged cork cells, those of the inner part provided with thickened, pitted, inner walls; small-celled parenchyma immediately below the cork, including solitary crystals; a closed ring of strongly pitted stone cells, and additional, infrequent groups of stone cells on the inside of the closed ring; phloem characterized by medullary rays 5–8 cells wide, with fairly numerous groups of 3–6 and less frequent solitary, strongly thickened fibres between the rays, the solitary fibres and groups being sheathed by cells containing solitary crystals; cells with lustrous, reddish-brown contents included in the phloem parenchyma. Bark of the closely related *A. kamerunensis* Perk. et Gilg. similar in structure but the cells with reddish-brown contents apparently absent. Species of *Halesia* and *Styrax* are cultivated in Britain for ornamental purposes.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Alniphyllum, Bruinsmea, Halesia,* Pamphilia, Pterostyrax,* Styrax.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

(Alniphyllum), Bruinsmea, Halesia, (Huodendron), (Pamphilia), (Pterostyrax), Styrax.

LITERATURE

(i) *On General Anatomy*

Mildbraed **1533**, Perkins **1689**.

(ii) *On Wood Structure*

den Berger **179**, **182**, Howard **1088**, Janssonius **1154**, Kanehira **1206**, **1209**, Record **1780**, **1818**, **1843**, **1851**, Record and Hess **1886**, Tang **2231**, Yamabayashi **2478**.

186. SYMPLOCACEAE

(FIG. 205 on p. 888; FIG. 206 on p. 892)

SUMMARY

(i) GENERAL

Trees or shrubs belonging to the single genus *Symplocos* of which there are a number of species in the warmer parts of Asia, Australia, and America. The more interesting microscopical features include the occurrence of bladder-like **secretory structures** on the leaf; the usually rubiaceous **stomata;** the scalariform perforation plates in the xylem vessels of the young stem.

(ii) WOOD

Vessels small and solitary, perforation plates scalariform, often with spiral thickening, members moderately to very long. **Parenchyma** apotracheal, diffuse or in short uniseriate lines. **Rays** usually up to 3–5 cells wide and high, markedly heterogeneous. **Fibres** with bordered pits and often with spiral thickening; of medium length to moderately long.

LEAF

Dorsiventral. **Hairs** absent from some species, e.g. *S. odoratissima* Choisy, when present often sclerenchymatous, with thin transverse septa. Multicellular or stalked glands with palisade-like secretory cells recorded and figured from the scale leaves of *S. klotzschii* Brand by Chirtoiu (395). Unicellular **water-secreting structures,** swollen like a bladder towards the outside, but with the constricted lower end entering the leaf through a rosette of very small epidermal cells, recorded by Solereder on both surfaces in some species, but confined to the upper side in others. Secretory organs, consisting of rounded spaces traversed by numerous, elongated, interwoven cells and serving to exude a gum-like substance, also present at the leaf margin of *S. adenophylla* Wall. and in the leaf teeth of *S. glomerata* King. **Cuticle** often striate or ridged, especially in *S. itatiaiae* Wowra. **Epidermis** consisting of cells with straight or sinuous anticlinal walls; papillose, with cuticular ridges connecting the papillae on the lower surface in *S. neriifolia* S. et Z. Epidermal cells on both surfaces said by de Boer (214) to be pitted in *S. odoratissima* Choisy, especially the outer walls of the cells on the upper surface. **Stomata** confined to the lower surface; generally rubiaceous. Continuous or interrupted **hypoderm** present beneath the upper epidermis of a number of species. **Mesophyll** including 1 or more layers of palisade cells, some of them being arm cells, and rather variable spongy parenchyma consisting, in some species, of stellate cells, and occasionally somewhat sclerosed. Intercellular spaces not well developed in the spongy tissue of *S. odoratissima.* Vascular bundles of the lateral **veins** surrounded by a fibrous sheath in some species, e.g. *S. odoratissima*; sometimes vertically transcurrent. Branches of the sclerenchyma around the bundles frequently extending into the mesophyll. **Petiole** of *S. odoratissima* exhibiting, in transverse sections, a median, cylindrical vascular strand, somewhat flattened towards the adaxial surface, and supported by a fibrous sheath in the pericyclic region. Small, accessory, cylindrical strands present in the wings. Structure similar in *S. paniculata* Wall. Stone cells recorded by Solereder in the parenchyma of the petiole in *S. adenophylla* Wall. **Crystals** solitary or, more rarely, clustered, the former variable in size. Clusters in the mesophyll and small crystalliferous cells in the phloem of the midrib recorded by de Boer in *S. odoratissima.* **Fat-like bodies,** sometimes termed alumina bodies, said to occur in the palisade tissue of all species. These bodies stain red if treated with a weak alkaline solution of brasilin, but appear as rounded or irregular masses of colourless material if treated with eau de Javelle. **Tannin** recorded in the unlignified tissue of *S. odoratissima.*

AXIS

STEM (Fig. 205 J)

Cork arising superficially. Primary **cortex** containing numerous stone cells in *S. adenophylla* Wall. **Pericycle** including a ring composed of strands of fibres interspersed with branched stone cells. Secondary **phloem** containing fibres in *S. adenophylla.* **Xylem** in the form of a continuous cylinder traversed by narrow rays in *S. paniculata* Wall. (Fig. 205 J). Vessels with scalariform perforation plates. **Fat-like bodies,** similar to those in the leaf, stated sometimes to occur in the primary cortex.

WOOD (Fig. 206 A, and E–G)

Vessels small (mean tangential diameter less than 100 μ) and often angular; exclusively solitary, apart from apparent tangential pairs due to overlapping ends; 15 to over 100 per sq. mm.; often with spiral thickening.

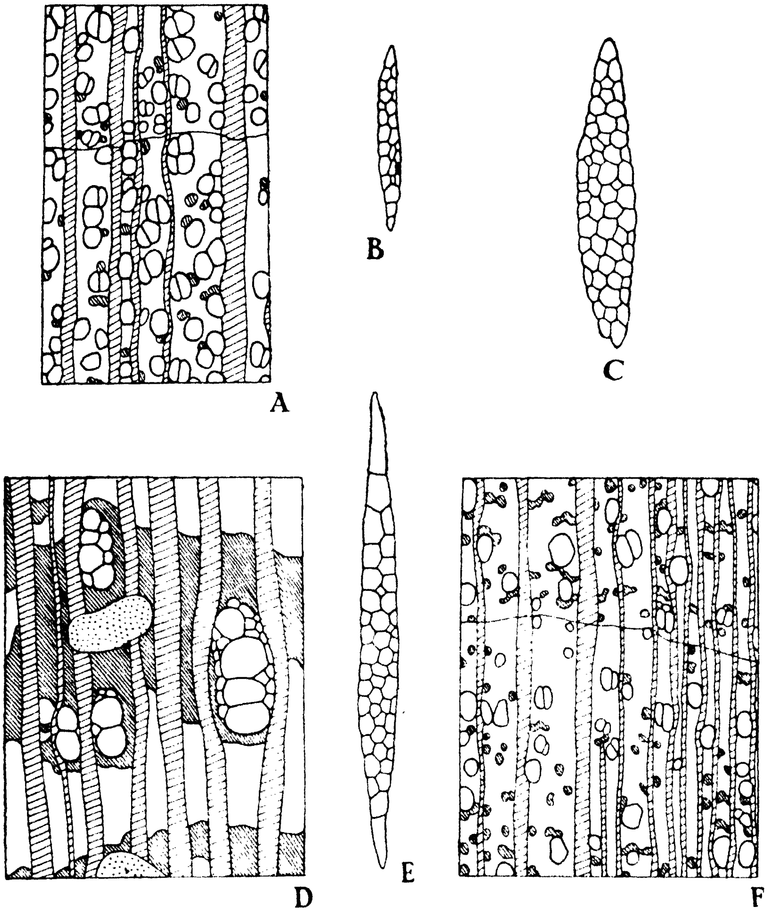


FIG. 206. *SALVADORACEAE*, B–D; *SYMPLOCACEAE*, A and E–G
A, *Symplocos arisanensis* Hayata. B, *Salvadora persica* Linn. C, *S. persica* Linn. D, *S. persica* Linn. E, *Symplocos arisanensis* Hayata. F, *S. adenophylla* Wall. G, *S. fasciculata* Zoll.

Perforation plates scalariform, usually with more than 20 fine bars, occasionally slightly reticulate. Intervascular pitting usually very rare, scalariform to opposite; pitting to ray and wood parenchyma typically small and round, occasionally scalariform. Occasionally with tyloses (1154). Mean member length 0·9–1·3 mm. **Parenchyma** apotracheal, as scattered cells or short uniseriate lines, the latter sometimes finely reticulate. Strands of 4–8 cells. **Rays** typically up to 3–5 cells wide, but occasionally not more than 2 cells wide (1206) and up to 9–12 cells in *S. spicata* Roxb. Less than 1 mm. high in a few species, but typically very much higher; uniseriate rays numerous and composed entirely of upright cells; mostly 10–15 rays per mm.; typically heterogeneous (Kribs's Types I and II A) with 3 to many marginal rows of upright cells, but almost homogeneous in *S. tinctoria* (L.) L'Her. (1886). Perforated ray cells sometimes present (358). **Fibres** with distinctly bordered pits on both radial and tangential walls. Walls of medium thickness. Spiral thickening commonly present (1206, 1800). Mean length 1·2–2·2 mm.

Taxonomic Notes

In the *Genera Plantarum*, *Symplocos* was treated by Bentham and Hooker as a member of the Styracaceae, but it is now generally regarded as the sole genus in a distinct family. *Symplocos* is distinguished from most of the Styracaceae by the absence of stellate hairs. The various taxonomic positions in which *Symplocos* has been placed have been discussed by Chirtoiu (395).

The secondary xylem of *Symplocos* differs from that of the Styracaceae in having solitary vessels, elongated pits between vessels and rays, and in the occurrence of spiral thickening, commonly in the vessels and occasionally in the fibres. It is in general of a slightly less specialized character.

Economic Uses

de Boer (214) has described the structure of the leaf of *S. odoratissima* Choisy in some detail. Medicinal properties have been attributed to this species which was included in the fourth edition of the Dutch Pharmacopoeia. The bark of the same species is stated to possess astringent properties. Lodh bark, at one time regarded as comparable with that of *Cinchona*, is derived in India from *S. racemosa* Roxb. Lendner (1357) has described and figured the anatomical structure of the leaf of *S. lanceolata* (Mart.) A. DC. used as a substitute for Maté tea (see p. 385).

The wood of *S. spicata* Roxb. var. *australis* Benth. is used to some extent for veneers in Australia (525).

Genus Described

Symplocos.

Literature

(i) *On General Anatomy*

de Boer **214**, Chirtoiu **395**, Lendner **1357**.

(ii) *On Wood Structure*

den Berger **182**, Chalk and Chattaway **358**, Dadswell **525**, Hess **960**, Janssonius **1154**, Kanehira **1206**, **1209**, Lecomte **1334**, Record **1783**, **1800**, **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**, Yamabayashi **2478**.

187. OLEACEAE

(Fig. 205 on p. 888; Fig. 207 on p. 894; Fig. 208 on p. 898)

Summary

(i) General

A family widely distributed in temperate and tropical regions and consisting mainly of trees and shrubs but also including climbers. One of the most widespread features is the occurrence on the leaves of **peltate trichomes** which sometimes have a secretory function. These appear to the naked eye or under a lens as transparent or sunken dots. Groups of secretory trichomes constitute the **extra-floral nectaries** which are common in some of the genera. The **stomata,** most numerous on and usually confined to the lower surface, are generally ranunculaceous. The **mesophyll** frequently contains sclerenchymatous idioblasts. In the young stem only a few noteworthy features have been recorded. The **cork** arises superficially. The **pericycle** is marked by a composite and continuous ring of sclerenchyma in some species or by a more interrupted ring in others, but the degree of interruption varies considerably with age. In some species continuous rings are not very persistent. Small acicular or prismatic **crystals** occur widely in both stem and leaf. Sphaerites of calcium malate recorded by Pfeiffer (1707) in *Fraxinus excelsior* Linn.

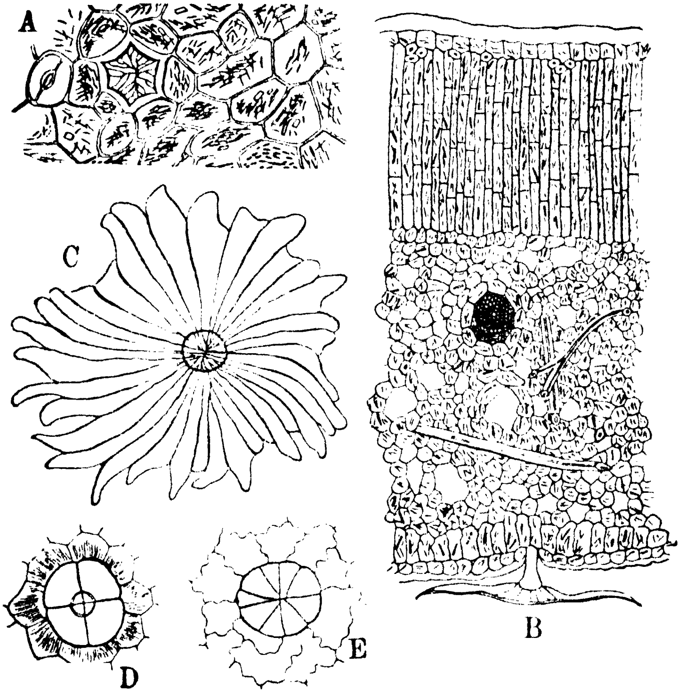


Fig. 207. *OLEACEAE*

A, Epidermis of the lower side of the leaf of *Forestiera porulosa* Poir., showing a depressed gland and the numerous small raphides in the cells. B, Transverse section of the leaf of *Olea europaea* L. with sclerenchymatous fibres and a peltate hair, and showing abundant small raphides. C, Peltate hair of *Olea europaea* L. in surface-view. D, Glandular hair of *Jasminum officinale* L. E, Glandular hair of *Linociera micrantha* Mart.—By Solereder.

(ii) Wood

Vessels typically small, with variable arrangement including exclusively solitary, numerous multiples of 4 or more cells and dendritic, commonly ring-porous and with spiral thickening in temperate species, perforations simple, intervascular pitting typically very small to minute and never large, pits to parenchyma similar, members of medium length to moderately short. **Parenchyma** typically paratracheal, varying from a few cells round the vessels to aliform or locally confluent; absent from a few genera and occasionally diffuse; terminal bands often present. **Rays** typically low and narrow, 1–4 cells wide, usually 2–3 cells wide, heterogeneous to homogeneous. **Fibres** usually with small, simple pits, but with bordered pits in a few genera, occasionally septate and rarely with spiral thickening, of medium length to moderately short. **Vasicentric tracheids** with spiral thickening present in a few genera.

LEAF

Dorsiventral (Fig. 207 B). **Hairs** consisting for the most part of peltate trichomes (Fig. 207 C) each having a unicellular stalk and a shield with exclusively vertical divisions; sometimes glandular (Fig. 207 D–E) or appearing as transparent or sunken dots in the leaf (Fig. 207 A). Groups of the secretory type of hair frequently form **extra-floral nectaries** in species of *Forestiera, Fraxinus, Olea, Osmanthus, Phillyrea, Syringa.* The sugary secretion from the extra-floral nectaries of *Osmanthus ilicifolius* Mouillef. is very attractive to wasps, which may be seen in large numbers on and around the bushes when secretion is proceeding actively (Metcalfe 1499). Unicellular or uniseriate hairs often occur amongst the peltate trichomes. White dots recorded on the upper surface of the leaf of *Nyctanthes arbortristis* Linn. and bodies resembling **cystoliths** in the neighbouring cells of the same species. **Cuticle** frequently striate. **Epidermis** consisting of cells with straight or sinuous anticlinal walls. Lower epidermis of certain species of *Fraxinus* provided with coronulate papillae united by a network of ridges. **Hypoderm** infrequent; recorded below the upper epidermis in species of *Jasminum, Linociera, Noronhia.* **Stomata** most abundant on the lower surface, but recorded on the upper side as well in species of *Fraxinus* (section *Bumelioides*), *Ligustrum*, and *Menodora*; usually ranunculaceous. Stomata of 2 distinct sizes recorded in species of *Forestiera.* **Mesophyll** often including sclerenchymatous idioblasts (Fig. 207 B) in *Ligustrum, Linociera, Noronhia, Notelaea, Olea*; details of their shape and distribution valuable in the identification of species. **Petiole,** in transverse sections through the distal end, exhibiting a shallow, crescentic vascular strand in × *Forsythia intermedia* Zabel., *F. suspensa* Vahl., *Ligustrum sempervirens* Lingelsh., *L. nepalense* Wall., *L. sinense* Lour., *L. vulgare* Linn. (Fig. 205 M), and *Olea europaea* Linn.; structure similar but with the ends of the vascular strand somewhat or very much incurved in *Fontanesia fortunei* Carr., *Notelaea excelsa* Webb. et Bert., *Osmanthus delavayi* Franch., *Phillyrea angustifolia* Linn. (Fig. 205 I), *P. decora* Boiss. et Bal., *Syringa vulgaris* Linn., and with a much deeper crescentic strand in *S. villosa* Vahl. (Fig. 205 K). Median vascular strand still more deeply crescentic in *Jasminum humile* Linn. and other species of *Jasminum* (Fig. 205 G); in the form of a closed cylinder, flattened on the adaxial side, in *Chionanthus retusus* Lindl. et Paxt., *C. virginica* Linn. (Fig. 205 H), *Fraxinus excelsior* Linn. (Fig. 205 F), *Osmanthus ilicifolius* Mouillef.; similar but with the cylinder dissected into separate bundles in *Fraxinus ornus* Linn. Small accessory bundles in the wings noted in the same species of *Chionanthus, Fraxinus, Jasminum, Osmanthus*, and *Syringa.*

Small, acicular, and prismatic **crystals** (Fig. 207 A–B) of calcium oxalate occur in the epidermis or mesophyll.

The leaf of 'dune forms' of *Fraxinus americana* Linn. described by Starr (2188) as differing from those of mesophytic specimens of the same species in the following respects. Cells of the epidermis taller and with the outer wall and cuticle thicker; a mixture of short conical and long hairs present on the lower surface (glabrous in the mesophytic form); palisade tissue deeper, tending to consist of 4 layers of cells; vessels in the midrib and fibres around the vascular bundles more numerous. For the **developmental anatomy** of the leaf of *Ligustrum vulgare* Linn. see Schwarz's (2059) article. Leaf structure of *Ligustrum* described by Mansfeld (1433) as very constant throughout the genus, but species sometimes recognizable from the epidermal structure. For further details see Mansfeld's paper. Metcalfe (1498) has described small microscopical differences between the closely related species *Fraxinus oxycarpa* Willd. and *F. pallisae* A. J. Wilmot ex Pallis.

AXIS

YOUNG STEM (Fig. 205 L and N)

Epidermis frequently including sclerosed cells in *Fraxinus*; outer walls often strongly cuticularized, e.g. in *Jasminum*. **Cork** arising superficially in species of *Chionanthus*, *Fontanesia* (early phellogen only), *Forestiera*, *Forsythia*, *Fraxinus*, *Jasminum*, *Ligustrum*, *Notelaea*, *Olea*, *Osmanthus*, *Phillyrea*, *Syringa*; late phellogen formed below the layers of collenchyma in the cortex of *Fontanesia fortunei* Carr., or in the pericycle of *F. phillyreoides* Labill. Cork described by Solereder as often composed of large and radially elongated cells; seen to be homogeneous in some of the species examined at Kew, but including solitary or grouped, much-thickened cells in others; stratified into alternating layers of cells with thin and thick walls respectively, e.g. in *Chionanthus virginica* Linn. Outer part of the primary **cortex** sometimes composed of chlorenchyma, that of *Jasminum humile* Linn. (Fig. 205 L) consisting of palisade cells; described by Solereder as frequently collenchymatous; containing stone cells in *Olea europaea* Linn. according to Solereder and largely composed of sclerenchymatous fibres in *Fontanesia* and *Fraxinus* according to Lingelsheim (1376). Similar elements noted at Kew in the cortex of species of *Jasminum* (Fig. 205 L), *Ligustrum*, *Notelaea*, and *Osmanthus*. **Pericycle** containing a composite and continuous ring of sclerenchyma in species of *Chionanthus*, *Forestiera*, *Fraxinus* (pro parte), *Linociera*, *Notelaea*, *Olea* (slightly interrupted in some species), *Osmanthus*, *Phillyrea*; with a similar but more interrupted ring in species of *Fontanesia*, *Forsythia*, *Fraxinus*, *Jasminum*, *Ligustrum*, *Syringa*. Fibres and stone cells also recorded or noted in the secondary **phloem** in *Fontanesia*, *Fraxinus*, *Ligustrum sempervirens* Lingelsh., *Nyctanthes arbortristis* Linn. (Majumdar 1423), and *Syringa*, but sclerenchymatous elements in this tissue all relatively short in *Jasminum*, *Ligustrum*, *Olea*, *Phillyrea*. **Xylem,** in all examined species, forming a closed cylinder traversed by narrow rays; vessels mostly with simple perforations, but occasional scalariform plates also recorded (see 'Wood'). **Pith** said to be homogeneous in *Olea* and *Phillyrea*; heterogeneous in *Chionanthus*, *Fontanesia*, *Forsythia*, *Fraxinus*, *Ligustrum*, *Syringa*; sometimes septate in *Jasminum*. A system of inversely orientated **cortical vascular bundles,**

never directly connected with the main axial ring, recorded by Majumdar (1423) in *Nyctanthes arbortristis* Linn. Cortical bundles in this species were apparently not observed by previous investigators. **Secretory canals** and **cells** absent from all of the material examined at Kew. **Crystals** infrequent; solitary types noted in the pith in a few species of *Ligustrum.*

Anatomical differences between **'weeping'** and **erect** forms of *Fraxinus excelsior* Linn. not very definite or constant according to Löw (1397). For interspecific differences in the stem structure of *Ligustrum* see Mansfeld (1433).

WOOD (Fig. 208 D–K)

Vessels typically small (less than 100 μ mean tangential diameter) apart from those of the pore-zone, and sometimes extremely small (less than 25 μ), but medium-sized (100–200 μ) in *Linociera*; exclusively solitary or almost so in *Forsythia*, *Ligustrum*, and *Syringa*, multiples of 4 or more cells common in *Linociera* p.p., *Mayepea*, *Nyctanthes*, *Olea*, *Schrebera* p.p., and sometimes sufficiently numerous to give a radial pattern, particularly in *Olea* (Fig. 208 F); with the vessels grouped in broad oblique masses (dendritic) in some species of *Chionanthus* (Fig. 208 K), but not in the Javanese species described by Janssonius (1154), *Osmanthus* (1206, 1886), and in *Phillyrea*; usually more than 20 and up to about 200 per sq. mm., but less numerous in *Linociera*; ring-porous or semi-ring-porous in some species of *Chionanthus*, *Fontanesia* (1851), *Forsythia*, *Fraxinus*, *Jasminum*, *Ligustrum*, *Phillyrea* (1851), *Schrebera*, and *Syringa*; with spiral thickening in some species of *Chionanthus*, *Fontanesia* (1851), *Forsythia*, *Jasminum* (2001), *Ligustrum*, *Menodora* (1868), *Notelaea*, *Osmanthus* (1206), *Phillyrea* (2158), and *Syringa.* Perforations typically simple, but Solereder has recorded some scalariform plates with 1 or more bars in *Fontanesia*, *Forsythia*, and *Syringa.* Intervascular pitting alternate, very small to minute; reported (1206) to be vestured in *Forestiera*; pits to ray and wood parenchyma similar to the intervascular pitting, but with a few larger pits in *Ligustrum.* Tyloses sometimes present, e.g. in *Chionanthus* and *Fraxinus*, and sclerotic tyloses are reported (434) to occur sporadically in *Ligustrum glomeratum* Bl.; solid deposits sometimes present, e.g. in *Notelaea* and *Olea.* Mean member length 0·2–0·6 mm. **Parenchyma** typically predominantly paratracheal, but predominantly apotracheal, as scattered cells in *Forsythia* and *Nyctanthes*; the paratracheal parenchyma varying from a few cells touching the vessels (scanty) to complete sheaths (vasicentric) that tend locally to become aliform or confluent; sometimes absent or extremely sparse (apart from terminal bands), e.g. in *Ligustrum*, *Phillyrea*, and *Syringa*; sometimes with distinct terminal bands, e.g. in some species of *Chionanthus*, *Fraxinus*, *Linociera*, *Olea*, and *Phillyrea.* Occasionally containing crystals, e.g. in *Chionanthus.* Strands usually up to 8 cells, but sometimes fewer, e.g. in *Chionanthus*; fusiform cells reported (1886) to be common in the early wood of some species of *Fraxinus.* **Rays** typically 2–3 cells wide, sometimes up to 4 or 5 cells, e.g. in some species of *Fraxinus*, *Nyctanthes*, *Schrebera*, and *Syringa*; wholly uniseriate and composed entirely of upright cells in *Menodora* (1886); less than 1 mm. high; uniseriates tending to be few and low, usually composed of a few upright cells only, but sometimes of mixed upright and procumbent cells, e.g. in *Chionanthus*, *Fraxinus*, *Phillyrea*, and *Syringa*; 5–16 rays per mm.; heterogeneous (Kribs's Type II)

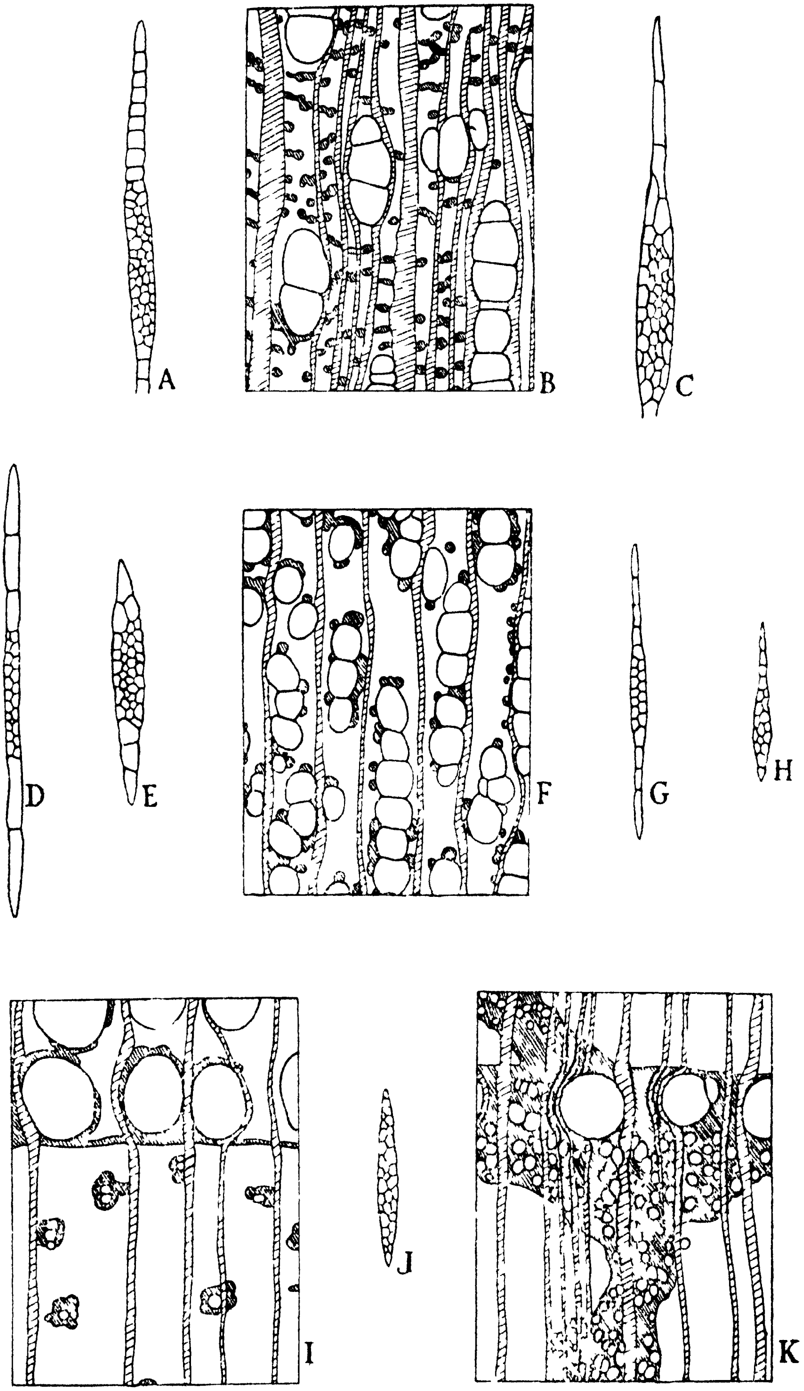


Fig. 208 *STYRACACEAE*, A–C. *OLEACEAE*, D–K.

A, *Halesia diptera* Linn. B, *Styrax polyspermum* C. B. Clarke. C, *S. polyspermum* C. B. Clarke. D, *Linociera insignis* C. B. Clarke. E, *Schrebera golungensis* Welw. F, *Olea hochstetteri* Baker. G, *Forsythia suspensa* Vahl. H, *Chionanthus retusus* Lindl. et Paxt. I, *Fraxinus excelsior* Linn. J, *F. excelsior* Linn. K, *Chionanthus retusus* Lindl. et Paxt.

to homogeneous (Kribs's I and II); heterogeneous rays usually with 1–3 marginal rows of square or upright cells, but sometimes with 4–10 rows, e.g. in some species of *Forestiera*, *Forsythia*, *Ligustrum*, and *Linociera*; the marginal cells sometimes square and not distinguishable in shape from the procumbent cells in tangential sections, e.g. in *Chionanthus*, *Phillyrea*, and *Syringa*; commonly homogeneous (Kribs's Type I) in *Fraxinus* and almost homogeneous in *Chionanthus*. Sometimes containing numerous small crystals, e.g. in *Ligustrum* and *Schrebera*. Tending to be storied in some species of *Fraxinus* and sometimes locally in echelon in other genera. **Fibres** usually with small simple or indistinctly bordered pits, but with distinctly bordered pits in some species of *Chionanthus* (1886), *Fontanesia* (2158), *Forsythia*, *Jasminum*, *Menodora* (1886), *Nyctanthes* (2158), and *Osmanthus* (1886); the pits usually mostly in the radial walls, but sometimes numerous in the tangential walls when distinctly bordered, e.g. in *Forsythia*; Janssonius refers to fibre-tracheids in the outer part of the ring in *Ligustrum glomeratum* Bl. Septate in *Ligustrum* and *Schrebera* and reported to be occasionally septate in some species of *Olea* (1154), *Fraxinus insularis* Hemsl. (1206), and *Notelaea*. Walls thin to very thick. Spiral thickening observed or reported in *Fontanesia* (1851), *Forsythia*, *Jasminum*, *Menodora* (1886), and *Syringa*, and with a few spirally thickened fibre-tracheids round the vessels in *Ligustrum vulgare* L. Mean length 0·8–1·45 mm. **Vasicentric tracheids** with spiral thickening observed in *Chionanthus retusus* Lindl. et Paxt. and *Phillyrea media* L. and reported by Garratt (744) in *Olea* sp. **Growth rings.** The development of the annual ring in *Fraxinus* has been described by Chalk (349, 351) and by Lodewick (1385, 1386).

TAXONOMIC NOTES

Sax and Abbe (2001), after investigating the chromosome numbers and anatomy of the secondary xylem of certain members of the Oleaceae, concluded that the family is a very natural one in which the intergeneric differences are clearly defined. The Jasminoideae are rather distinct from the Oleoideae comprising the genera *Chionanthus*, *Forestiera*, *Forsythia*, *Ligustrum*, *Olea*, and *Syringa*. The same authors also found that 'on the whole there is a suggestive parallelism between chromosome number, grafting relationships, and anatomical structure'.

ECONOMIC USES

Olive oil is derived from the fruits of *Olea europaea* Linn. An account of the anatomy of the seedling and mature plant of the Olive has been published by Alquati (24). Manna is a substance with laxative properties, exuded from cracks or incisions in the bark of the Manna Ash (*Fraxinus ornus* Linn.). Medicinal properties have also been attributed to *Chionanthus* of which an anatomical account has been published by Youngken and Feldmarr (2497). A yellow dye was at one time extracted from the flowers of *Nyctanthes arbortristis* Linn. Species of *Jasminum* (Jasmine), *Ligustrum* (Privet), and *Syringa* (Lilac) are commonly cultivated in Britain for ornamental purposes. Species of *Jasminum* are also used in perfumery.

The most important timbers produced by this family are the Ashes, *Fraxinus* spp., of which the best known are the European Ash, *F. excelsior* Linn., and the American White Ash, *F. americana* Linn. Ash has a world-wide reputation for toughness and is used for a great number of purposes that are exacting in this respect, e.g. for agricultural tool handles, motor bodies, and sports requisites such as tennis-racquet frames, hockey-sticks, &c. The wood of olive is attractively streaked and that of the East African Olive, *Olea hochstetteri* Bak., which is a large tree, is sometimes exported, particularly for flooring. The wood of the European Olive, *Olea europaea* Linn., is used in southern Europe for making souvenirs for the tourist trade, and some other species, many of which are only small trees, produce fine-textured, durable woods that are used locally for carving, agricultural tools, wagon work, sleepers, fuel, &c.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Chionanthus,* Fontanesia,* Forestiera,* Forsythia,* Fraxinus,* Jasminum,* Ligustrum,* Linociera, Menodora, Noronhia, Notelaea,* Nyctanthes, Olea,* Osmanthus,* Phillyrea,* Syringa.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Chionanthus, (Fontanesia), Forestiera, Forsythia, Fraxinus, Haenianthus, Jasminum, Ligustrum, Linociera, Mayepea, (Menodora), Noronhia, Nyctanthes, Olea, (Osmanthus), Schrebera, Syringa.

LITERATURE

(i) *On General Anatomy*

Alquati **24**, Cookson **2516**, Lingelsheim **1376**, Löw **1397**, Majumdar **1423**, Mansfeld **1433**, Metcalfe **1498**, **1499**, Pfeiffer **1707**, Sax and Abbe **2001**, Schwarz **2059**, Starr **2188**, Youngken and Feldmarr **2497**.

(ii) *On Wood Structure*

Allsopp and Misra **22**, Amaldi **25**, Bienfait and Pfeiffer **197**, Brown, F. B. H. **282**, Brown, H. P., and Panshin **288**, **289**, Chalk **349**, **351**, Chalk *et al.* **360**, Chalk and Rendle **365**, Chowdhury **411**, Cockrell **434**, Garratt **744**, Giordano **787**, Greguss **2522**, Hale **870**, Hanson and Brenke **888**, Holmes **1078**, Howard **1088**, Isenberg **1124**, Janssonius **1154**, Jones **1191**, Kanehira **1206**, **1209**, Lecomte **1334**, Lodewick **1385**, **1386**, Metcalfe **1498**, Pearson and Brown **1679**, Record **1783**, **1800**, **1843**, **1851**, **1868**, Record and Hess **1886**, Sax and Abbe **2001**, Scott **2075**, Stone **2203**, Tang **2230**, **2231**, Yamabayashi **2478**.

188. SALVADORACEAE

(FIG. 206 on p. 892; FIG. 209 on p. 902; FIG. 210 on p. 904)

SUMMARY

Trees and shrubs, sometimes with spines in the leaf axils. The family occurs in Tropical Africa and the Mascarene Islands. The occurrence of **interxylary phloem** in *Dobera* and *Salvadora* provides one of the most interesting anatomical characters of young stems. The wood exhibits the following characters. **Vessels** mostly in small groups of multiples and irregular clusters, perforations simple, intervascular pitting alternate and very small, pits to parenchyma similar, members very to extremely short. **Parenchyma** about the vessels and the phloem strands and often linking the latter in broad bands, fusiform cells common, storied. **Rays** up to 3–5 cells wide, usually with very few uniseriates, generally composed entirely of square or slightly procumbent cells, the shorter rays sometimes storied. **Fibres** with simple pits, very short. **Included phloem** of the 'foraminate' type present in 2 of the 3 genera described.

LEAF

Dorsiventral or isobilateral. **Hairs** infrequent, mostly consisting of unicellular trichomes; poorly developed peltate hairs also recorded in *Dobera* and *Platymitium* (Fig. 209 C–D). **Epidermis** consisting of tetragonal or polygonal cells as seen in surface view; 2-layered on both sides of the leaf in *Salvadora persica* Linn. **Hypoderm** recorded on the upper side in *Azima tetracantha* Lam. **Stomata** equally abundant over the whole surface in species of *Dobera* and *Salvadora* with thick, centric leaves; confined to the lower side of the dorsiventral leaf of *Azima tetracantha*; rubiaceous in *Salvadora*. **Mesophyll** of the isobilateral leaves of *Dobera roxburgii* Planch. and *Salvadora persica* composed of palisade cells surrounding a central, pith-like tissue devoid of chlorophyll. Vascular bundles of the **veins** in *Salvadora persica* said by Sabnis (1977) to be embedded in the colourless part of the mesophyll and surrounded by green bundle sheaths. Bundles accompanied by sclerenchyma above and below in *Salvadora oleoides* Decne., but sclerenchyma in the corresponding region in *S. persica* consisting only of stone cells on the lower side of the larger bundles. 'Water storage tracheids with pitted markings' also recorded by Sabnis in the mesophyll between the veins in both species. **Petiole** of *Azima tetracantha* (Fig. 210 G), in transverse sections through the distal end, exhibiting a thick, slightly crescentic vascular strand with small vessels in the xylem arranged in very definite radial rows, the strand being supported on the abaxial side by large, conspicuous, widely spaced strands of fibres. Structure somewhat similar in *Salvadora persica*, but ends of the vascular strand inwardly directed and the xylem including well-developed interxylary phloem (Fig. 210 I); fibres in the pericyclic region of this species solitary or in very small groups. Interxylary phloem described as extending into the midrib of *S. persica* by Balwant Singh (119). Clustered **crystals** of uncertain chemical composition occur in the mesophyll of all investigated species, particularly in *Dobera* and *Salvadora* (Fig. 209 A–B), those in *S. persica* according to Balwant Singh (119) situated in large cells, previously mistaken for water-storage elements by Sabnis (1977) through the crystals having disappeared during the preparation of his sections. **Fatty bodies** recorded in the mesophyll of dried leaves.

AXIS

YOUNG STEM (Fig. 210 J–K)

The following description refers mainly to *Azima tetracantha* Lam. (Fig. 210 J) and *Salvadora persica* Linn. (Fig. 210 K) cultivated at Kew.

Cork arising superficially; consisting of cells with wide lumina. Primary **cortex** narrow, parenchymatous. **Pericycle** including conspicuous, widely spaced strands of very thick-walled fibres opposite the vascular bundles, the fibre strands in *A. tetracantha* being much larger than those in *S. persica*; cells between the fibre strands also slightly lignified in *A. tetracantha*. **Xylem** and **phloem** of both species in the form of a circle of distinct bundles separated by fairly broad medullary rays 3–5 cells wide, the latter consisting of lignified cells where traversing the xylem. Vessels with simple perforations. Strands of **interxylary phloem** present in *S. persica* but not in *A. tetracantha* (see also under 'Wood' and 'Anomalous Structure'). **Pith** broad, parenchymatous, and somewhat spongy, but including a few slightly lignified, pitted cells. Cluster **crystals** observed in the cortex and pith and solitary ones in the rays where traversing the phloem in *A. tetracantha*; no crystals seen at Kew in *S. persica*, but druses recorded in the cortex of this species by Balwant Singh (119).

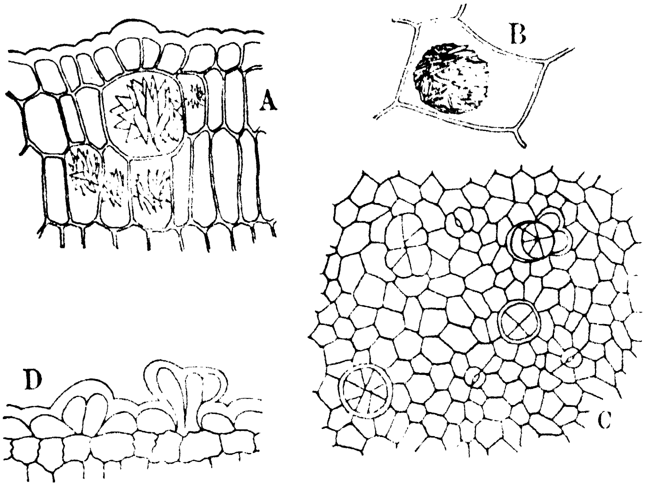


Fig. 209. *SALVADORACEAE*

A, Transverse section through a portion of the leaf of *Dobera roxburghii* Planch. with characteristic clustered crystals; above the large clustered crystal a group of 2 epidermal cells projects in a papillose manner. B, Smaller clustered crystal from the interior of the leaf of *Salvadora persica* L. C, D, Epidermis of the leaf of *Platymitium loranthifolium* Warb. with cell-groups projecting more or less distinctly after the manner of peltate hairs; C, in surface-view; D, in transverse section.—By Solereder.

WOOD (Fig. 206 B–D)

Vessels sometimes tending to be of 2 distinct sizes, with medium-sized vessels partially surrounded by extremely small, tracheid-like members (Fig. 206 D); mostly in multiples of 2–4 cells and irregular clusters; 2–10 per sq. mm. Perforations simple. Intervascular pitting alternate, very small to minute; pits to ray and wood parenchyma similar. Mean member length 0·13–0·2 mm. **Parenchyma** paratracheal, varying from a few cells (scanty) to complete sheaths (vasicentric) round the vessels and often joining with the broad bands of parenchyma that surround and link together the strands of included phloem. Strands of 1–4 cells, fusiform cells often very common. Storied. **Rays** up to 3–5 cells wide; less than 1 mm., but usually more than 1 story, high; uniseriate rays usually very few, but moderately abundant in some specimens of *Salvadora persica* Linn.; composed of mixed square and upright cells; 8–14 rays per mm.; composed entirely of square or slightly procumbent cells that are indistinguishable in tangential sections, but with some more distinctly procumbent cells in one specimen of *S. persica*. With numerous solitary crystals in one specimen of *S. oleoides* Decne. Storied in specimens in which the rays are not characteristically more than 1 story high. **Fibres** with simple pits, more numerous in the radial than in the tangential walls. Walls moderately thick to thick. Length about 0·6 mm. (100). **Included (interxylary) phloem** of the 'foraminate' type (*c.l. foraminulatum*) present in all the material of *Salvadora* examined and reported by Solereder in *Dobera*; with round to oval strands of included phloem surrounded and commonly linked together by parenchyma (see also under 'Young Stem' and 'Anomalous Structure').

ROOT

The following particulars concerning the root of *Salvadora persica* Linn. recorded by Balwant Singh (119).

Diarch or tetrarch when young; usually with a small central pith, but primary xylem groups sometimes meeting at the centre. Older roots consisting mainly of xylem but including interxylary phloem originating in the same way as that in the stem.

ANOMALOUS STRUCTURE

Strands of interxylary phloem occur in the xylem of *Dobera* and *Salvadora*; extending into the root and through the petiole into the midrib of the leaf in *Salvadora*. Interxylary phloem in *Salvadora* arises centripetally, on the inside of the normal cambium according to Balwant Singh (119), thus differing in mode of development from the centrifugal interxylary phloem of *Strychnos* (Loganiaceae). Cellular disorganization occurs in the interxylary phloem of both stem and root when these organs are sufficiently mature (see also under 'Young Stem' and 'Wood').

ECONOMIC USES

The shoots of the Mustard or Tooth-brush Tree (*Salvadora persica* Linn.) are sometimes used as tooth-brushes by the natives of India, Ceylon, and Arabia.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Azima,* Dobera, Platymitium, Salvadora.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

(Azima), (Dobera), Salvadora.

LITERATURE

(i) *On General Anatomy*

Balwant Singh **119**, Sabnis **1977**.

(ii) *On Wood Structure*

Bailey and Tupper **100**, Chalk and Chattaway **362**, Pfeiffer, H. **1712**, Record **1843**, **1851**, Singh **2104**.

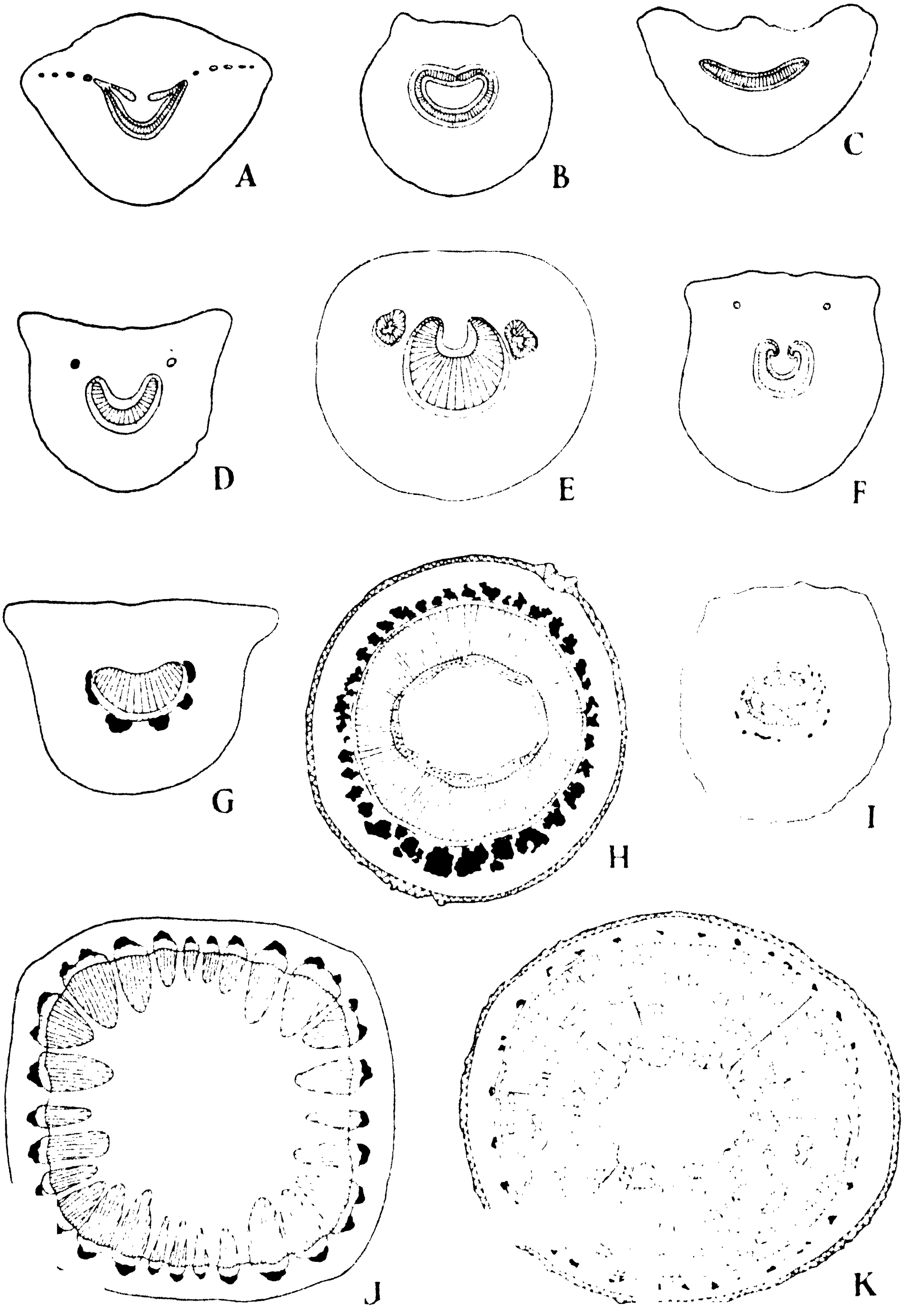


FIG. 210. *APOCYNACEAE*, A–F and H; *SALVADORACEAE*, G and I–K

A, *Alstonia macrophylla* Wall. Petiole ×8. B, *Landolphia klainei* Pierre. Petiole ×8. C, *Vinca difformis* Pourr. Petiole ×19. D, *Thevetia peruviana* Merrill. Petiole ×15. E, *Acokanthera spectabilis* Hook. f. Petiole ×17. F, *Picralima klaineana* Pierre. Petiole ×15. G, *Azima tetracantha* Lam. Petiole ×19. H, *Trachelospermum jasminoides* Lem. Stem ×19. I, *Salvadora persica* Linn. Petiole ×31. J, *Azima tetracantha* Lam. Stem ×17. K, *Salvadora persica* Linn. Stem ×19.

189. APOCYNACEAE

(FIG. 91 on p. 402; FIG. 210 on p. 904; FIG. 211 on p. 906; FIG. 212 on p. 910)

SUMMARY

(i) GENERAL

A mainly tropical and sub-tropical family of very diverse habit, including trees, shrubs, lianes, and a few herbs. The cactus-like *Pachypodium namaquanum* Wall. is described separately on p. 913. The **leaf** is usually dorsiventral, or, more rarely, isobilateral. The outstanding anatomical characters are the universal occurrence of (i) **laticiferous canals** with variously coloured contents, and (ii) **intraxylary phloem.** The **stomata** are ranunculaceous in some members of the family and rubiaceous in others; sometimes a mixture of both kinds occurs in a single species. The **mesophyll** frequently contains 'spicular cells', whilst the spongy portion is sometimes gelatinized. In the axis the **cork** arises superficially, but the exact region of origin varies in different species. The **pericycle** is marked by a continuous ring or separate strands of characteristic white fibres. **Anomalous structure** of the axis occurs in the lianes, and takes the form of furrows lined with phloem or of interxylary phloem. **Crystals** of various types are sometimes useful for the identification of species.

(ii) WOOD

Vessels usually small but sometimes large, either exclusively solitary or with numerous multiples that sometimes give a radial or oblique pattern, perforations simple, intervascular pitting very small to minute, vestured, pits to parenchyma similar, members moderately short to moderately long. **Parenchyma** most commonly apotracheal, as scattered cells or narrow bands, sometimes with scanty paratracheal in addition; predominantly paratracheal in some genera and absent from genera with septate fibres. **Rays** (*a*) in woods without septate fibres, typically 2–3 cells wide or exclusively uniseriate and less than 1 mm. high, wider or higher in a few genera, heterogeneous, typically with 2–10 marginal rows but occasionally with more and occasionally almost homogeneous, cells often rounded (tang. section) with conspicuous intercellular spaces; (*b*) in woods with septate fibres, typically 3–5 cells wide and more than 1 mm. high, heterogeneous with many rows of large upright cells and often with more than 1 multiseriate part per ray, walls angular and intercellular spaces lacking, idioblasts suggesting oil or mucilage cells present in 2 genera. **Fibres** either with simple pits and septate or with bordered pits, which are sometimes large and distinct, and non-septate; usually of medium length, occasionally moderately to very short. **Latex tubes** present in the rays of several genera. **'Latex traces'** present in a high proportion of the genera.

LEAF

Dorsiventral in most instances, but isobilateral in *Nerium oleander* Linn. and *Aspidosperma quebracho* Schlecht. **Hairs.** (i) Simple uniseriate in species of *Beaumontia*, *Chonemorpha* (situated on cushions of epidermal tissue), *Echites*, *Lochnera*, *Trachelospermum*, *Wrightia*. (ii) Unicellular, sometimes resembling papillae, e.g. in *Allamanda*, *Lochnera*, *Nerium*, *Vinca*. (iii) Uniseriate, but with a series of compressed basal cells embedded in the epidermis in *Echites* (Fig. 211 A) and *Micrechites*. (iv) Branched hairs shaped like antlers in *Oncinotis* (Fig. 211 B). (v) Glandular shaggy hairs present at the base of the lamina and on the petiole of many members of the family. **Cork warts** recorded on the lower surface in *Carpodinus*, *Chilocarpus*, *Clitandra*, *Landolphia*, *Leuconotis*, *Pycnobotrya*. **Epidermis** somewhat variable, consisting, on the upper surface, of specially large cells in species of *Allamanda*, *Beaumontia*, *Cerbera*, *Tabernaemontana*; locally 2-layered in species of *Alstonia*, *Chilocarpus*, *Chonemorpha*, *Echites*; papillose on the upper surface in *Acokanthera spectabilis* (Sond.) Benth. according to Poulson (1738); lower epidermis of *Allamanda verticillata* Desf. described by the same author as bearing strongly cuticularized, pillar-like papillae with slightly enlarged heads, and a papillose lower epidermis also recorded in *Apocynum cannabinum* Linn. by Holm (1047) as well as in other species of *Apocynum* by Ballard (117). A papillose lower epidermis is also mentioned by Solereder in species of *Alstonia*, *Apocynum*, *Landolphia*, and *Willughbeia*. **Hypoderm** of 1 or more layers, sometimes on both sides of the leaf, recorded in species of *Acokanthera* (Poulsen 1738), *Bousigonia*, *Carpodinus*, *Chilocarpus*, *Ichnocarpus*, *Lepiniopsis*, *Leuconotis*, *Micrechites*, *Nouettea*, *Parabarium*, *Sclerodictyon*, *Willughbeia*. **Stomata** variable; rubiaceous types recorded in species of *Allamanda*, *Carpodinus*, *Chilocarpus*, *Chonemorpha*, *Clitandra*, *Cylindropsis*, *Echites*, *Kopsia*, *Landolphia*, *Lepiniopsis*, *Michrechites*, *Parabarium*, *Plumeria*, *Strophanthus*, *Vinca*, *Willughbeia*, *Winchia*; said to be ranunculaceous in species of *Carissa*, *Cerbera*, *Craspidospermum*, *Ecdysanthera*, *Hunteria*, *Leuconotis*, *Lochnera*, *Melodinus*, *Rhynchodia*, *Tabernaemontana*; according to Poulsen (1738) surrounded by several rings of radially arranged subsidiary cells in *Acokanthera spectabilis*, which thus differs from other members of the family. Ranunculaceous and rubiaceous stomata occur together in some species, but each kind is characteristic of different members of a single genus in other instances. Stomata of *Nerium oleander* Linn. and *N. odorum* Soland. confined to pits on the lower side of the leaf, with hairs at the entrances to the pits; described as present on both surfaces but most numerous on the lower side in *Lochnera*

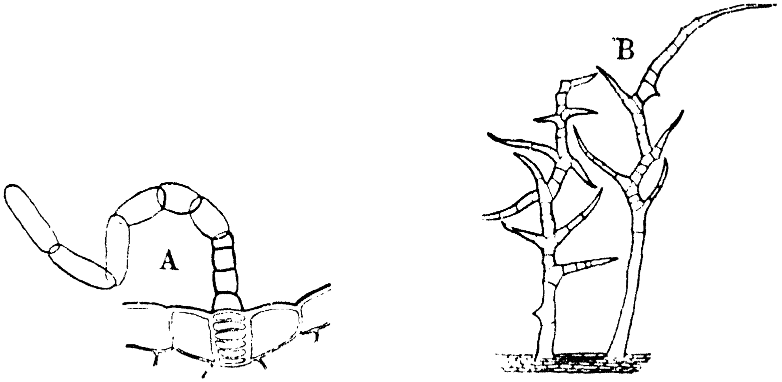


FIG. 211. *APOCYNACEAE*
A, Trichome of *Echites peltata* Vell. B, Branched hairs of *Oncinotis hirta* Oliv.—By Solereder.

pusilla K. Schum. by Sayeedud-Din (2008). **Mesophyll.** Some of the palisade cells sclerosed in *Aspidosperma quebracho* Schlecht. Spongy mesophyll mucilaginous in many species of *Carpodinus*, *Chilocarpus*, *Clitandra*, *Couma*, *Cylindropsis*, *Hancornia*, *Landolphia*, *Vahea*, *Willughbeia*. 'Spicular fibres', in the form of extensions of the sclerenchyma around the veins, recorded in the mesophyll of species of *Bousigonia*, *Michrechites*, *Neocouma*, *Sclerodictyon*, *Trachelospermum*.

Vascular bundle of the **midrib** typically bicollateral in *Apocynum cannabinum* Linn. and probably in other genera. **Petiole** (Fig. 210 A–F), in transverse sections through the distal end, exhibiting a crescentic, median vascular strand in many genera and species, this type of structure having been observed in species of all of the genera examined at Kew. Vascular strand usually in the form of a shallow arc, but comparatively deep in a few species, e.g. *Beaumontia grandiflora* Wall. and *Picralima klaineana* Pierre; ends of the vascular strand consisting wholly of phloem and strongly incurved in *Alstonia macrophylla* Wall. (Fig. 210 A); ends of the bundle in *Landolphia klainei* Pierre (Fig. 210 B) practically in contact with one another and so forming an almost cylindrical strand somewhat flattened on the adaxial side. Intraxylary phloem present in all of the species examined. Small accessory bundles in the wings of the petiole noted in species of *Alstonia*, *Beaumontia*, *Mascarenhasia*, *Nerium*, *Picralima*, *Pleiocarpa*, *Strophanthus*, *Thevetia*, *Trachelospermum*, and recorded by Solereder in *Vinca*. Vascular strand of the petiole strongly supported in the pericyclic region by fibres similar to those in the corresponding region of the stem in *Picralima* and *Pleiocarpa*, but fibres poorly developed in or absent from the corresponding position in the other genera examined at Kew.

Secretory cells, with granular contents resembling latex, present in the form of a definite layer below the palisade tissue in species of *Cleghornia*, *Echites*, *Kopsia*, *Tabernaemontana*. **Laticiferous canals** always accompany the veins, and, in species of *Acokanthera*, *Beaumontia*, *Chilocarpus*, *Dipladenia*, *Echites*, *Hunteria*, *Lepiniopsis*, *Leuconotis*, *Lochnera*, *Parabarium*, *Plumeria*, *Thevetia*, *Vinca*, sometimes extend into the mesophyll, reaching the epidermis in *Acokanthera spectabilis* according to Poulsen (1738), as well as in *Allamanda verticillata* and *Carissa grandiflora* A. DC. Contents of the laticiferous canals sometimes capable of being drawn out in the form of elastic threads on breaking the stem, e.g. in *Parameria vulneraria* Radlk.; bright yellow in species of *Leuconotis*, pale red in *Parabarium* and *Parameria*, greenish in *Trachelospermum*. Clustered, solitary, small prismatic **crystals** and styloids of calcium oxalate recorded. Clustered crystals occur in enlarged cells of the mesophyll in species of *Apocynum* and *Oncinotis* as well as in large idioblasts appearing as transparent dots in the leaf in *Hunteria africana* K. Sch. Solitary crystals occasional in the epidermis of species of *Acokanthera* (Poulsen 1738), *Alstonia*, *Cerbera*, *Gonioma*, *Hunteria*.

ECOLOGICAL ANATOMY OF THE LEAF

An anatomical comparison between 'juvenile' and 'adult' leaves of *Parsonsia heterophylla* A. Cunn. and *P. capsularis* (Forst.) R. Br., climbers on trees and shrubs at the forest margin in New Zealand, has been made by Bird (199). The following particulars refer to *P. heterophylla*.

Juvenile Leaf. Infrequent, unicellular hairs present on both surfaces. Epidermis composed of isodiametric cells as seen in transverse section, the cells of the upper being rather larger than those of the lower surface. Stomata confined to the lower surface. Mesophyll including 1 layer of palisade cells. Vascular bundles sheathed by thin-walled, spherical, parenchymatous cells. A few cluster crystals of calcium oxalate present in the upper part of the spongy mesophyll.

Adult Leaf. Epidermis strongly cuticularized and provided with thickened anticlinal walls. Epidermal cells especially thickened at the leaf margins. Hypodermis present below the upper epidermis in the region of the vascular bundles and also at the leaf margins. Mesophyll including 2–3 layers of palisade tissue. Vascular bundles surrounded by a sheath of thick-walled, parenchymatous cells. Cluster crystals of calcium oxalate more numerous than in the juvenile leaf.

AXIS

YOUNG STEM (Fig. 210 H)

Cork nearly always arising superficially, but a deep-seated phellogen noted in *Rhazya orientalis* A. DC.; consisting of wide, thin-walled cells, e.g. in *Nerium oleander* Linn., stratified into alternating layers, with and without thickened walls, e.g. in *Geissospermum*. Cork cells filled with crystals in *Alstonia scholaris* R. Br. Primary **cortex** in some species containing solitary or grouped stone cells. **Pericycle** usually broad and almost invariably containing white, sometimes mucilaginous, unlignified fibres, either isolated or in groups; walls of the fibres often concentrically zoned; the individual fibres, especially in relatively old material, consisting of alternate, constricted and enlarged portions. No pericyclic fibres seen in *Rhazya orientalis* A. DC. **Phloem** sometimes containing solitary or grouped stone cells. **Xylem,** in all of the species examined at Kew, in the form of a continuous cylinder traversed by narrow rays, but wider rays probably present in other genera and species. Vessel perforations mostly simple, but occasional scalariform plates also recorded (see 'Wood').

Intraxylary phloem present in all examined members of the family, except the specialized *Pachypodium* (see p. 913), either in the form of a ring or as isolated bundles at the margin of the pith. Additional arcs of phloem more deeply seated in the pith, also recorded in species of *Lyonsia*, *Mandevilla*, *Parsonsia*. The intraxylary phloem in old stems of *Apocynum cannabinum* Linn. and *Willughbeia firma* Linn. becomes converted, through the activity of a cambium, to inversely orientated medullary bundles. **Pith** frequently containing sclerosed elements, e.g. in species of *Acokanthera*, *Alstonia*, *Carissa*, *Echites*, *Gonioma*, *Landolphia*, *Picralima*, *Pleiocarpa*, *Rhazya*, *Tabernaemontana*; consisting of homogeneous, thin-walled, pitted cells below soil level in *Apocynum cannabinum* Linn. (Holm 1047). The **developmental anatomy** of the shoot of *Vinca* has been described by Cross and Johnson (510). **Laticiferous canals** always present, and generally situated in the primary cortex, pericycle, phloem, pith, and sometimes in the medullary rays. For further details concerning the laticiferous system of *Beaumontia* see Woodworth's (2464) article. Solitary and clustered **crystals** common in the unlignified tissues of most of the species examined at Kew; styloids recorded or observed in the stem of species of *Carissa*, *Cerbera*, *Pleiocarpa* (numerous in the phloem), *Tabernaemontana*. No crystals observed in *Amsonia tabernaemontana* Walt., *Apocynum androsaemifolium* Linn., *Rhazya orientalis* A. DC., *Strophanthus capensis* A. DC., *Trachelospermum divaricatum* K. Schum., *Vinca difformis* Pourr., *V. minor* Linn. An annular zone of clustered crystals recorded in the cortex of *Forsteronia corymbosa* Mey.

WOOD (Fig. 212 A–H)

Vessels typically small (less than 100 μ mean tangential diameter) and often very small (25–50 μ), but medium-sized (100–200 μ) in some species of *Alstonia*, *Aspidosperma*, *Carpodinus*, *Condylocarpon*, *Couma*, *Funtumia*, *Geissospermum*, *Ichnocarpus*, *Kickxia*, *Macoubea*, *Pagiantha*, *Parahancornia*, *Paralstonia*, *Rauwolfia*, *Vallaris*, and *Voacanga*, and sometimes large (more than 200 μ) in some species of *Anodendron*, *Carruthersia*, and *Landolphia*; exclusively solitary in several genera of the Plumiereae, e.g. *Acokanthera* (786), *Alyxia*, *Aspidosperma*, *Condylocarpon*, *Diplorrhynchus*, *Geissospermum*, *Gonioma*, *Hunteria*, *Microplumeria* (1886), *Picralima*, *Pteralyxia*, *Rauwolfia*, and *Vallesia*, and also in *Carissa*, *Carpodinus*, *Carruthersia*, *Craspidospermum*, *Epigynum*, *Ichnocarpus*, and *Landolphia*; typically with numerous multiples in the other genera, the multiples often of 4 or more cells, and sometimes with a few clusters; long multiples or loosely associated groups of vessels sometimes producing a radial or oblique pattern, e.g. in *Alstonia* (Fig. 212 C), *Pterochrosia*, *Stemmadenia*, *Tabernaemontana*, *Thevetia*, and *Voacanga*; very variable in number, mostly 10–50 per sq. mm.; fewer than 5 per mm. in some species of *Alstonia*, *Aspidosperma*, *Cameraria*, *Couma*, *Dyera*, *Funtumia*, *Macoubea*, *Plumeria*, *Vallaris*, and *Zschokkea*; sometimes more than 100 per sq. mm., e.g. in *Carissa*, *Odontadenia*, *Stemmadenia*, and *Tabernaemontana*; with a tendency to be ring-porous in some species of *Alyxia*, *Ichnocarpus*, *Malouetia*, and *Tabernaemontana*, and, according to Record (1851), in *Allamanda*; spiral thickening not observed, but reported by Solereder as occurring in species of *Carissa*, *Tabernaemontana*, and *Vinca*. Perforations simple and typically small in relation to the diameter of the vessels and with wide rims; some short scalariform plates observed in *Alyxia* and reported (1886) in *Anacampta* and *Rauwolfia duckei* Mgf., and occasional scalariform plates to ray cells observed in *Lepiniopsis*. Intervascular pitting alternate, very small to minute; vestured (78); pits to ray and wood parenchyma similar. Contents rare; tyloses observed or reported in some species of *Alstonia*, *Aspidosperma*, *Couma*, *Craspidospermum*, *Macoubea*, and *Wrightia*, those of *Aspidosperma aquaticum* Ducke reported by Milanez (1525) to be sclerosed. Mean member length 0·3–1·0 (mostly 0·5–0·7 mm.). **Parenchyma** predominantly apotracheal in most genera but predominantly paratracheal in some and absent from others. The apotracheal parenchyma most commonly as scattered cells or short, irregular, uniseriate lines (Fig. 212 H), but in more distinct uniseriate bands in some species of *Cameraria*, *Cerberiopsis*, *Dyera*, *Funtumia*, *Geissospermum*, *Gonioma*, *Parahancornia*, *Plumeria*, *Vallaris*, and *Zschokkea*, and with bands 2–3 cells wide in some species of *Alstonia* (Fig. 212 C) and *Pterochrosia*; Williams (2430) refers to broad continuous bands in *Condylocarpon*, but no such bands are present in the material examined by the author of *C. intermedium* Muell.-Arg. and *C. myrtifolium* Muell.-Arg. Sometimes

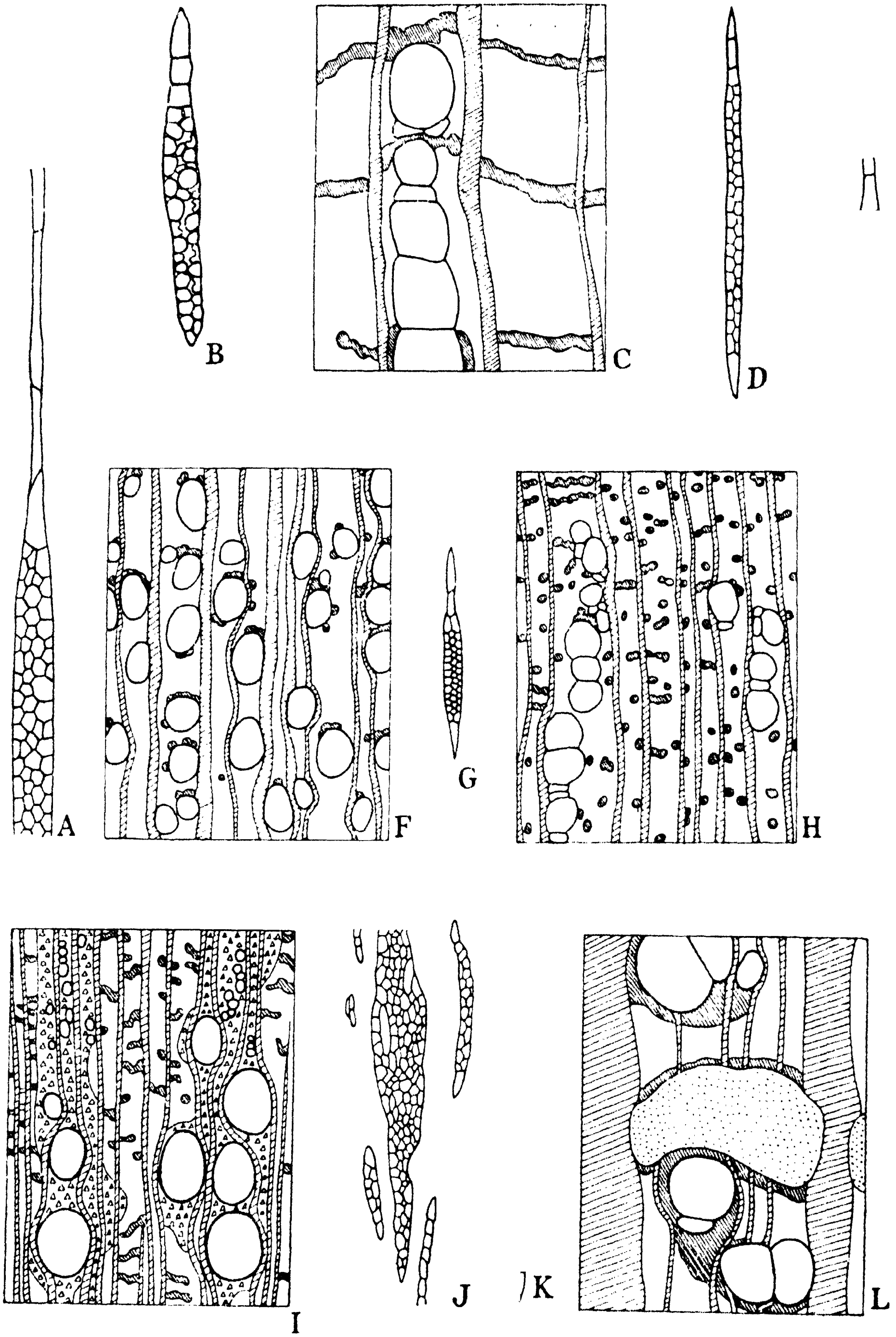


FIG. 212. *APOCYNACEAE*, A–H; *ASCLEPIADACEAE*, I–L

A, *Ervatamia corymbosa* King et Gamble. B, *Alstonia congensis* Engl. C, *A. congensis* Engl. D, *Funtumia latifolia* Stapf. E, *Voacanga africana* Stapf. F, *Diplorrhynchus mosambicensis* Benth. G, *Picralima umbellata* Stapf. H, *Plumeria sucuuba* Spruce. I, *Periploca graeca* Linn. J, *P. graeca* Linn. K, *Asclepias fruticosa* Linn. L, *Leptadenia lancifolia* Decne.

with scanty paratracheal parenchyma in addition, e.g. in *Alstonia*, *Aspidosperma*, and *Dyera*, and Brown (1679) states that some paratracheal parenchyma is always present (in Indian species). Predominantly paratracheal, vasicentric to aliform, and often limited to the outer edge and sides of the vessels, with or without some scattered cells, in *Aspidosperma* p.p., *Carpodinus*, *Carruthersia*, *Diplorrhynchus* (Fig. 212 F), *Gerbera*, and *Ichnocarpus*. Typically limited to very rare cells about the vessels or absent from the genera with septate fibres, *Anartia* (1886), *Conopharyngia*, *Ervatamia*, *Odontadenia*, *Peschiera* (1886), *Stemmadenia*, *Tabernaemontana*, and *Voacanga*. Terminal bands sometimes present, e.g. in *Aspidosperma*, *Carruthersia*, *Cerbera*, and *Vallaris*. Chambered crystalliferous cells present in many genera but seldom abundant. Milanez (1525) refers to enlarged sclerotic parenchyma cells in *Aspidosperma aquaticum* Ducke. Strands typically up to 8 cells, sometimes fewer, e.g. in *Cerbera*. Parenchyma variable in *Alstonia* and *Aspidospermum*, that of the former varying from a few scattered cells, e.g. in *Alstonia spectabilis* R. Br. and *A. subsessilis* Miq., to regular bands 2–3 cells wide, e.g. in *A. angustiloba* Miq. and *A. congensis* Engl.; Milanez (1528) distinguishes 4 groups of *Aspidosperma* spp. according to whether the parenchyma is terminal, diffuse, metatracheal, or paratracheal. **Rays.** (*a*) *Genera without septate fibres* (Fig. 212 B, D, and G). Typically up to 2–3 cells wide, but exclusively uniseriate in some species of *Cameraria*, *Cerbera*, *Plumeria*, *Pterochrosia*, *Thevetia*, and *Zschokkea*, and up to 4–6 cells wide in some genera, e.g. *Alyxia*, *Aspidosperma*, *Condylocarpon* p.p., *Diplorrhynchus*, *Dyera*, *Excavatia*, *Gonioma*, *Ochrosia* (1154), *Paralstonia*, *Rauwolfia*, *Vallesia*, and *Wrightia*, and up to 9 cells in *Ichnocarpus frutescens* R. Br.; rays typically rather short, distinctly less than 1 mm. high and often less than 0·5 mm., but higher in *Alyxia*, *Carruthersia*, *Ichnocarpus*, *Kopsia*, *Lanugia*, *Lepiniopsis*, *Ochrosia*, and *Pagiantha*; uniseriate rays moderately numerous and usually composed entirely of upright cells, except in woods with uniseriate rays only; 8–23 rays per mm., but rather fewer in some species of *Rauwolfia*; heterogeneous (Kribs's Types II A and III), usually with 4–10 marginal rows of square or upright cells, but seldom with more than 3 rows in *Alstonia*, *Alyxia* p.p., *Ambelania*, *Aspidosperma*, *Craspidospermum*, *Dyera*, *Funtumia*, *Geissospermum*, *Parahancornia*, *Picralima*, *Plumeria*, and *Rauwolfia*, commonly with 10 or more rows in *Alyxia* p.p., *Carruthersia*, *Kopsia*, *Lanugia*, *Lepiniopsis*, and *Mascarenhasia*; almost homogeneous, with few to moderately numerous uniseriates in *Aspidosperma* and *Geissospermum*, and, according to Record and Hess (1886), in *Ambelania*, *Cameraria*, and *Hancornia*. Sometimes with chambered crystals, e.g. in *Cerberiopsis*, *Diplorrhynchus*, *Echites*, *Ochrosia*, *Paralstonia*, *Vallesia*, and *Wrightia*, and sometimes with crystals in the ordinary upright cells. Walls often rounded in tangential section, with conspicuous intercellular spaces; the cells sometimes kidney-shaped, with a concave radial wall, e.g. in *Alstonia* (Fig. 212 B). Record and Garratt (1884) refer to the occurrence of ray tracheids in *Gonioma kamassi* E. Mey., but these have not been observed by the author. (*b*) *Genera with septate fibres* (Fig. 212 A and E) (*Conopharyngia*, *Ervatamia*, *Odontadenia*, *Stemmadenia*, *Tabernaemontana*, and *Voacanga*).[1] Mostly up to 3–5 cells wide, only 2 cells

[1] Record and Hess (1886) report septate fibres also in *Anartia*, *Bonafousia*, *Peschiera*, and *Stenosolen*; the rays of these genera have not been examined by the author.

wide in *Odontadenia speciosa* Benth. and up to 6 cells in *Voacanga* p.p.; typically more than 1 mm. high; uniseriate rays numerous and often high, composed entirely of tall upright cells; usually with 19–20 rays per mm., rather fewer in *Ervatamia* and *Voacanga* p.p., and up to 23 per mm. in *Stemmadenia*; markedly heterogeneous (Kribs's Type I and II A), with many marginal rows of wide and tall upright cells, which are in marked contrast, in tangential sections, to the relatively short groups of small procumbent cells; often with more than 1 multiseriate part per ray (Fig. 212 E). The upright cells sometimes containing crystals or crystal-sand; a few swollen cells suggesting oil or mucilage cells present in some species of *Stemmadenia* and *Voacanga*. Walls angular in tangential section and with few or no intercellular spaces. Chalk and Chattaway (358) report perforated ray cells as occurring in *Funtumia* and *Gonioma* and as very common in *Odontadenia* and *Tabernaemontana*. **Fibres** septate and with simple pits, which are almost entirely limited to the radial walls, in *Anartia* (1886), *Bonafousia* (1886), *Conopharyngia*, *Ervatamia*, *Odontadenia*, *Peschiera* (1886), *Stemmadenia*, *Stenosolen* (1886), *Tabernaemontana*, and *Voacanga*; in the other genera typically with bordered pits, more numerous on the radial than on the tangential walls, except in the genera with solitary vessels; the borders sometimes large and distinct, e.g. in *Alstonia*, *Diplorrhynchus*, *Plumeria*, and *Rauwolfia*; the borders sometimes very small or absent, e.g. *Ichnocarpus*, *Lacmellia*, *Macoubea*, and *Malouetia*. Walls typically thin to moderately thin, but sometimes moderately thick, e.g. in *Aspidosperma*, *Diplorrhynchus*, *Gonioma*, and *Hunteria*. Janssonius (1154) refers to the occurrence of single crystals in the septate fibres of *Voacanga grandifolia* Rolfe. Mean length 0·6, e.g. in *Ambelania* (2379), to 1·6 mm., e.g. in *Rauwolfia* (100) and *Alstonia*, mostly 1·0–1·3. **Vasicentric tracheids** sometimes present in *Condylocarpon* and reported by Janssonius to be occasionally present in *Kopsia*. **Latex tubes** present in the rays of some species of *Alstonia*, *Ambelania*, *Cerberiopsis*, *Conopharyngia*, *Couma* (1886), *Dyera*, *Hancornia* (1886), *Ichnocarpus*, *Macoubea*, *Mascarenhasia*, *Nerium*, *Ochrosia*, *Parahancornia*, *Peschiera* (1886), *Pterochrosia*, *Stemmadenia*, and *Tabernaemontana*.

'Latex traces.'[1] Large radial channels or strands, often up to half an inch in height and usually occurring in whorls, observed or reported in *Alstonia*, *Ambelania*, *Aspidosperma*, *Bonafousia*, *Couma*, *Dyera*, *Funtumia*, *Himatanthus*, *Lacmellia*, *Macoubea*, *Malouetia*, *Microplumeria* (?), *Neocouma*, *Parahancornia*, *Peschiera*, *Plumeria*, *Rauwolfia*, *Stemmadenia*, *Stenosolen*, *Tabernaemontana*, *Thevetia*, *Vallaris*, and *Zschokkea*. **Growth rings** and cambial activity in the tropics have been studied by Coster (481) in *Alstonia*, *Plumiera*, and *Thevetia* and by Link (1377) in *Strophanthus*. **Interxylary (included) phloem** of the foraminate type present in *Lyonsia* (see also under 'Anomalous Structure' below).

---

[1] These structures have been described by den Berger (178), Desch (567), and Eggeling and Harris (624) and various terms suggested. The above term was suggested by Eggeling and Harris as indicative of the two most distinctive characteristics of the feature, as studied in *Alstonia*, namely, the presence of latex tubes in the tissue and the origin of the tissue in the traces from the leaves and axial buds. In the living tree the 'latex traces' consist of solid strands of tissue, but in dry timber these have often disintegrated, leaving open canals or cavities.

ANOMALOUS STRUCTURE

Several types of anomalous structure recorded by Solereder, especially in certain lianes. (i) Xylem furrowed, with phloem situated in the furrows, the cambium extending between the xylem and phloem throughout the furrow, e.g. in species of *Allamanda*, *Alstonia*, *Condylocarpon*, *Echites*, *Lyonsia*, *Parsonsia*, and *Tabernaemontana*. (ii) Stem furrowed when young, but furrows subsequently becoming embedded in the xylem owing to proliferation of the latter, new furrows being formed at the outer periphery of the xylem at the same time and later becoming embedded in the same way. Transverse sections thus exhibit radially elongated islands of phloem irregularly scattered throughout the xylem. This anomaly recorded in a stem of *Condylocarpon* sp. 7·5 cm. in diameter. (iii) Irregularly shaped islands of interxylary phloem, containing sieve tubes with wide lumina, occur in *Lyonsia straminea* R. Br. The interxylary phloem in this species, when first formed, includes no sieve tubes, these elements arising by transformation of the unlignified elements at a later stage. Large groups of unlignified tissue, in which sieve tubes were not observed, also recorded in *Echites* sp.

ROOT

Abundant **laticiferous canals** recorded by Holm (1047) in the secondary cortex of mature roots of *Apocynum cannabinum* Linn. and in the cortex of *Thevetia neriifolia* Juss. by Boulay (243). **Mycorrhiza** in members of the family have been investigated by Demeter (562).

PACHYPODIUM NAMAQUANUM WALL.

The morphology and anatomy of *Pachypodium namaquanum* Wall. is so specialized that it has been found most convenient to describe it separately. The following account is based on that by Lee (1339). The plant, which belongs to the Apocynaceae-Echitoideae, has a stout, fleshy, spiny stem about 6 ft. tall, resembling that of a cactus, but provided with a terminal group of leaves interspersed with flowers. The stem surface is covered with fleshy protuberances arranged spirally, each protuberance having initially arisen just behind the stem apex in the axil of a leaf. There are 3 downwardly directed spines, of which the 2 lateral are longer than the median one, at the apex of each protuberance. The spines near the base of the stem are deciduous. The stem is largely composed of parenchymatous ground tissue, with branching and anastomosing vascular bundles embedded in it. There is also a main ring of bundles, separated from one another by wide medullary rays. The bundles differ from those of other members of the family in the absence of intraxylary phloem and in showing very little secondary thickening, increase in the girth of the stem being due to the irregular division of the cells of the ground tissue, in much the same way as in the Cactaceae. Lee suggests that the medullary bundles are homologous with the intraxylary phloem of other members of the Apocynaceae. He thus conforms with Worsdell (2470) who holds the opinion that the intraxylary phloem in general has arisen by the gradual reduction of xylem in an ancestral system of medullary bundles. The xylem of the medullary bundles in *Pachypodium* includes 'scalariform elements'.

Transverse sections of old spines show a small, central group of cells embedded in a mass of sclerenchyma. The original xylem groups are rendered obscure, because they merge with the surrounding ground tissue which is also highly lignified. The phloem elements become crushed and disorganized, eventually leaving small spaces in the sclerenchyma. The surface of the thorn is covered with a layer of tissue derived from the phellogen, which does not become suberized.

The revolute lamina of the leaf is densely velvety on both surfaces and covered with numerous, complex trichomes and emergences unlike those of other members of the Apocynaceae. The trichomes consist of a multicellular base, bearing unicellular, cuticularized ray cells. The small stomata on both surfaces are ranunculaceous. The mesophyll is not clearly differentiated into palisade and spongy portions, but appears to be isobilateral judging from Lee's figures. Transverse sections of the petiole exhibit an arc-shaped bundle, with strands of tissue, possibly to be interpreted as phloem, between the ends of the vascular strand.

Laticiferous elements, which Lee was unable to specify as cells or vessels, occur in the cortex and pith of the stem, as well as in the petiole, midrib, and lamina of the leaf and the cortex and pith of the spines.

TAXONOMIC NOTES

(i) GENERAL ANATOMY

The anatomical similarity between the Apocynaceae and Asclepiadaceae confirms that these families are closely related. The deep-seated phellogen and the absence of pericyclic fibres distinguishes *Rhazya orientalis* A. DC. from the other members of the family which have been examined. The peculiar habit, the possession of complex trichomes, and the absence of intraxylary phloem and other characters sharply distinguish *Pachypodium namaquanum* Wall. from other members of the Apocynaceae. These anatomical differences are so conspicuous that it may well be asked if the plant and the closely related *Adenium* have been assigned to the correct taxonomic position. If *Pachypodium* is truly a member of the Apocynaceae, the peculiar structure of the plant raises problems of considerable phylogenetic interest. The matter appears worthy of further investigation.

(ii) WOOD STRUCTURE

One group may be clearly distinguished from the rest of the family, having septate fibres, no parenchyma, and a rather different type of ray. This includes *Conopharyngia*, *Ervatamia*, *Odontadenia*, *Stemmadenia*, *Tabernaemontana*, and *Voacanga*, and probably also, judging by descriptions, *Anartia*, *Bonafousia*, *Peschiera*, and *Stenosolen*. The latex tubes and 'latex traces', characteristic of so many genera in the family as a whole, occur also in this group. The group bears a close resemblance to a group of genera in the Euphorbiaceae (see p. 1230).

Janssonius (1154) notes that *Rauwolfia* and *Ochrosia* are very similar to each other but distinct from the other genera he investigated.

Record (1842) has suggested that *Duckeodendron* is out of place in the Boraginaceae and Solanaceae and 'is a member of, or closely related to, the Apocynaceae'.

The species of *Alstonia* and *Aspidosperma* differ amongst themselves more widely than is usual within a genus.

ECONOMIC USES

Rubber, inferior in quality to that of *Hevea brasiliensis* (Para Rubber), is obtained from various members of the family. Some of the more familiar kinds include those derived from *Funtumia elastica* Stapf, various species of *Landolphia*, and root rubber derived from species of *Carpodinus*. The chief source of these kinds of rubber is West Tropical Africa, and they aroused considerable interest during the Second World War. A poor-quality gutta-percha was at one time obtained in Malaya from *Dyera costulata* Hook. f., but more recently this material has been used as an ingredient in chewing-gum according to Burkill (314A). The fruits of *Carissa carandas* Linn. are edible. Arrow poisons have been prepared in Africa from *Acokanthera* spp., whilst *Thevetia neriifolia* Juss., native of tropical America but now occurring in other tropical countries, is also the source of an arrow and fish poison. The anatomy of the plant has been fully described by Boulay (243).

Various plants with medicinal properties belong to the family. The seeds of *Strophanthus kombe* Oliv. are used as the source of a heart stimulant. The seeds of various other species of *Strophanthus*, which are sometimes substituted, may be distinguished, amongst other characters, by the different colour reactions they give when the cut transverse surface is moistened with 80 per cent. sulphuric acid. *S. kombe* Oliv. and *S. hispida* DC. give a green colour, whilst *S. courmentii* Sacleux, *S. emini* Aschers, *S. gratus* Franchet, *S. nicholsoni* Holmes, and *S. sarmentosus* DC. give various shades of red, rose, or violet, the tint being characteristic for each species. According to Santos (1994) the seeds of *S. cumingii* A. DC. have been used in the Philippine Islands to prepare an arrow poison.

An extract of Holarrhena Bark, derived from *Holarrhena antidysenterica* Wall., is used in India to control amoebic dysentery. The greyish-brown to reddish bark exhibits the following microscopical characters. Ground tissue parenchymatous, including abundant, thick-walled, pitted stone cells, the latter arranged in tangential masses towards the interior and in approximately circular or irregular groups towards the exterior; crushed remains of laticiferous canals with brown contents, accompanied, in some specimens, by secretory cells with similar contents; solitary prisms of calcium oxalate, mostly situated in cells adjoining the stone cells or in the lumina of the stone cells themselves; sporadic cells containing highly refractive oil drops; cork consisting of cells with brown thickenings to the outer tangential walls.

Quebracho Bark, derived from *Aspidosperma quebracho* Schlecht., has been used as the source of a tonic and febrifuge. The botanical source of this bark has been discussed by Rothlin (1960) and Short (2094). The bark is characterized microscopically by large, isolated phloem fibres, sheathed by cells containing prismatic crystals of calcium oxalate; abundant, 2–4 compound starch grains; groups of stone cells in the phloem and medullary rays.

Dita Bark, obtained from *Alstonia scholaris* R. Br. in India, Burma, and the Philippine Islands, is sometimes used as a febrifuge. According to Santos (1987) the commercial bark occurs as irregular pieces 6–15 cm. long, 5–8 cm. wide, and 3–7 cm. thick. The outer surface is rough and the inner surface sepia-coloured. The fracture is short, brittle, and uneven. Santos also records the following microscopical characters: thin-walled, closely pitted, slightly suberized, brownish cork cells; approximately cubical, sclerenchymatous cells in the cork region; stone cells with very thick, stratified walls perforated by numerous, usually branched pits; medullary ray cells containing small, spherical, often compound starch grains; crystals of calcium oxalate often situated in fibres; occasionally branched, laticiferous canals.

Apocynum, a drug derived from the rhizome and root of *Apocynum cannabinum* Linn. and other species of *Apocynum* has been used as a heart stimulant. The histology of the rhizomes of *A. cannabinum* and related species of *Apocynum* has been described by Ballard (117). The rhizomes of the species investigated differ from one another in diameter, colour, the number of rootlets, and similar characters. They are characterized microscopically by 5–10 layers of light-brown cork cells; a parenchymatous cortex including numerous laticiferous canals; cortical stone cells in *A. androsaemifolium* Linn., *A. hypericifolium* Ait., *A. pubescens* R. Br., and *A. urceolifer* G. S. Miller, but not in *A. cannabinum* Linn.; a narrow phloem containing few or no fibres; a relatively broad xylem; a pith in *A. androsaemifolium* but not in the other species.

Fibre is sometimes extracted from the bark of a few members of the family, but has never attained much importance. The silky floss from around the seeds of *Wrightia annamensia* Eber. et Dub. has likewise remained unimportant. The unicellular, hollow hairs of this species, according to Crevost and Reland (499), are 3–4 cm. long, with a rounded apex terminated by a small swelling, whilst the abruptly ending base bears transverse striations; the cell wall is lignified. A few of the hairs are branched.

The genus *Aspidosperma* furnishes some of the most important timbers of South America. These are divided by Record and Hess (1886) into 5 types: (1) the Acaranga group, e.g. *Aspidosperma desmanthum* Muell.-Arg., used for all kinds of heavy and durable construction; (2) the Quebracho Blanco group, e.g. *A. quebracho-blanco* Schl., used for heavy construction and in special demand for wheel-hubs and felloes and for bent-work; (3) the Carreto group, e.g. *A. curranii* Standl., used for bridging and railway sleepers; (4) the Peroba Rosa group, e.g. *A. peroba* Fr. Allem., used for all kinds of construction and for furniture and cabinet-work; and (5) the Boxwood group, e.g. *A. vargasii* A. DC., at one time exported as a boxwood substitute, but now only used locally. Similar to the latter is the Knysna or Kamassi Boxwood, *Gonioma kamassi* E. Mey., from South Africa, which is used for shuttles and bobbins. The above woods are all hard and dense, but the family also includes some outstandingly soft and light, white woods, which, having a fine grain, are very suitable for carving; such, for example, are Jelutong, *Dyera costulata* Hook. f., from Malaya, and Indian and African species of *Alstonia* and *Holarrhena*. It is, however, difficult to obtain long lengths of *Dyera* or *Alstonia* free from the 'latex traces' described above. The rootwood of *Alstonia spathulata* Bl. yields one of the lightest woods known, with a specific gravity of 0·06–0·08 (800).

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Acokanthera,* Allamanda,* Alstonia,* Amsonia,* Apocynum,* Aspidosperma, Beaumontia,* Bousigonia, Carissa,* Carpodinus, Cerbera, Chilocarpus, Chonemorpha, Cleghornia, Clitandra, Condylocarpon, Couma, Craspidospermum, Cylindropsis, Dipladenia, Ecdysanthera, Echites, Forsteronia, Funtumia, Geissospermum, Gonioma,* Hancornia, Holarrhena, Hunteria, Ichnocarpus, Kopsia, Landolphia,* Lepiniopsis, Leuconotis, Lochnera, Lyonsia, Mandevilla, Mascarenhasia,* Melodinus, Micrechites, Neocouma, Nerium,* Nouettea, Oncinotis, Pachypodium, Parabarium, Parsonsia, Picralima,* Pleiocarpa,* Plumeria, Pycnobotrya, Rauwolfia, Rhazya,* Rhynochodia, Sclerodictyon, Strophanthus,* Tabernaemontana, Thevetia,* Trachelospermum,* Vahea, Vinca,* Willughbeia, Winchia, Wrightia.*

* Represented in the Kew slide collection.

(ii) For Wood Structure

(Acokanthera), (Allamanda), Alstonia, Alyxia, Ambelania, (Anacampta), (Anartia), (Anodendron), Aspidosperma, (Bonafousia), Cameraria, Carissa, Carpodinus, Carruthersia, Cerbera, Cerberiopsis, (Condylocarpon), Conopharyngia, Couma, Craspidospermum, Diplorrhynchus, Dyera, Echites, Epigynum, Ervatamia, Excavatia, Funtumia, Geissospermum, Gonioma, (Hancornia), (Himatanthus), Holarrhena, Hunteria, Ichnocarpus, (Kibatalia), Kickxia, Kopsia, Lacmellia, Landolphia, Lanugia, Lepiniopsis, Macoubea, Malouetia, Mascarenhasia, (Microplumeria), (Neocouma), Nerium, Ochrosia, Odontadenia, Pagiantha, Parahancornia, Paralstonia, (Peschiera), Picralima, Plumeria, Pteralyxia, Pterochrosia, Rauwolfia, Stemmadenia, (Stenosolen), Tabernaemontana, Thevetia, Vallaris, Vallesia, Voacanga, Wrightia, Zschokkea.

Literature

(i) *On General Anatomy*

Ballard **117**, Bird **199**, Boulay **243**, Burkill **314A**, Crevost and Reland **499**, Cross and Johnson **510**, Demeter **562**, Desch **567**, Holm **1047**, Lee **1339**, Malcuit and David **1429**, Monachino **1551**, Poulsen **1738**, Rothlin **1960**, Santos **1987**, **1994**, Sayeedud-Din **2008**, Short **2094**, Sprument **2177**, Woodworth **2464**, Worsdell **2470**.

(ii) *On Wood Structure*

Bailey **78**, Benoist **170**, den Berger **178**, **179**, **182**, Besson **186**, Brit. Honduras For. Dept. **274**, Brown, F. B. H. **282**, Burgerstein **310**, **312**, Chalk *et al.* **360**, **364**, Chalk and Chattaway **358**, Cooper and Record **461**, Coster **481**, Dadswell **525**, Desch **567**, **574**, Eggeling and Harris **624**, Foxworthy **705**, Giordano **786**, Graefe **800**, Greguss **2522**, Harvey-Gibson **912**, **913**, Hopkinson **1083**, Howard **1088**, Janssonius **1154**, Jentsch **1175**, Jolly **1188**, Kanehira **1209**, **1212**, Kanehira *et al.* **1214**, Kuhlmann **1294**, Lecomte **1334**, Link **1377**, Mell and Brush **1486**, Messeri **1493**, Milanez **1525**, **1528**, Pearson and Brown **1679**, Pereira **1687**, Pfeiffer, H. **1712**, Pfeiffer, J. Ph. **1713**, Rafalski and Stryla **1771**, Record **1801**, **1811**, **1842**, **1843**, **1851**, **1884**, Record and Hess **1886**, Record and Mell **1894**, Riera **1937**, Scott **2075**, Stone **2202**, **2206**, Webber **2379**, Williams **2430**.

190. ASCLEPIADACEAE

(Fig. 212 on p. 910; Fig. 213 on p. 920)

Summary

(i) General

A family of shrubs and herbs; occurring mainly in warm countries and numerous in South Africa. In correlation with their close relationship, this family and the Apocynaceae have many features in common. Of these the most important are the universal occurrence of **laticiferous tubes** in both stem and leaf, together with the presence of **intraxylary phloem.** The **hairs** are mostly simple, unicellular or uniseriate, apart from the relatively infrequent unicellular glands and glandular shaggy hairs. The **leaf** is dorsiventral or isobilateral. The **stomata** are somewhat variable, although frequently rubiaceous. The pitcher-like leaves of *Dischidia rafflesiana* Wall. are noteworthy. In the young stem the **cork** arises superficially, the **endodermis** is often well defined, whilst the usually broad **pericycle** is marked by cellulose fibres which are solitary, in strands, or, in a few species, arranged in concentric zones. The **phloem** and **xylem** of the axis are usually in the form of continuous cylinders, traversed by narrow rays. Several types of **anomalous structure** occur in climbing species. The anatomy of a specialized, xeromorphic group of leafless members of the family from Madagascar has been investigated and described in some detail by Puech (1761). It is interesting to note that, apart from possessing photosynthetic stems, the structure of the axis of these plants conforms with that which is characteristic of the family in general. This applies also to the cactus-like species from South-West Africa examined by Zemke (2505).

(ii) WOOD

Vessels with numerous radial multiples or dendritic arrangement except in the climbers, sometimes ring-porous, perforations simple, intervascular pitting rather large and alternate, vestured, pits to ray cells similar, members very short. **Parenchyma** as scattered cells and irregular, uniseriate lines, or scanty paratracheal. **Rays** usually narrow and low and sometimes storied, but very large primary rays sometimes present. **Fibres** with small, bordered or simple pits, moderately to extremely short.

LEAF

Usually dorsiventral, but isobilateral in fleshy leaves of *Ceropegia* and *Hoya*, in the membranous leaves of *Marsdenia*, and, according to Sabnis (1977), in *Leptadenia spartium* Wt. **Hairs** mostly unicellular or uniseriate, but unicellular, hemispherical glands and shaggy hairs, similar to those of the Apocynaceae, recorded in *Dischidia*; shaggy hairs also reported in *Asclepias*. Glandular hairs observed at Kew by F. Ballard (unpublished) on the midrib of 58 species of *Gonolobus* as well as on the leaves of *Araujia sericofera* Brot., *Gongronema nepalense* Decne., *Marsdenia volubilis* T. Cooke. Glandular hairs noted by Sayeedud-Din and Suxena (2017) in *Sarcostemma*. **Cuticle** very thick in xerophilous species, e.g. in *Ceropegia*, or a coating of wax is sometimes secreted, e.g. according to Dastur and Saxton (543), in young leaves of '*Calotropis procera* R. Br.'. **Hypoderm** recorded by Solereder in species of *Hoya* and *Tylophora*, and by Trochain (2280) locally in *Leptadenia lancifolia* Decne. **Stomata** rubiaceous (but with cells parallel to the pore sometimes secondarily divided) in species of *Asclepias*, *Calotropis*, *Caralluma*, *Ceropegia*, *Cryptostegia*, *Glossonema*, *Hemidesmus*, *Hoya*, *Leptadenia*, *Marsdenia*, *Pentatropis*, *Pergularia*, *Periploca*, *Sarcostemma*, *Stephanotis*, *Tylophora*; cruciferous in species of *Hoya* and *Stapelia*; ranunculaceous in *Sarcostemma* p.p., *Solenostemma*, and *Vincetoxicum*. Sayeedud-Din and Suxena (2017) refer to the 'Tradescantia-type' with 4 subsidiary cells in *Stapelia*. **Mesophyll** described by Sabnis (1977) as consisting wholly of arm-palisade cells in *Pentatropis cynanchoides* R. Br. and of palisade tissue on the upper and arm-palisade tissue on the lower side in '*Calotropis procera* R. Br.' and *Glossonema varians* Benth. Sclerenchymatous fibres present in the mesophyll of *Dischidia rafflesiana* Wall. according to Solereder. **Petiole** (Fig. 213 A, B, C, E) in transverse sections through the distal end, exhibiting a crescentic, bicollateral vascular strand in all investigated material, notably in species of *Asclepias* (Fig. 213 E), *Calotropis*, *Ceropegia*, *Chlorocodon* (Fig. 213 B), *Cryptostegia*, *Gomphocarpus*, *Leptadenia*, *Marsdenia* (Fig. 213 C), *Periploca*, *Stephanotis*, *Vincetoxicum* (Fig. 213 A) examined at Kew or by Sayeedud-Din and Suxena (2017); small accessory strands in the wings noted in *Ceropegia*, *Cryptostegia*, *Gomphocarpus*, *Leptadenia*, *Marsdenia*, *Pergularia*, *Stephanotis*, *Vincetoxicum*. Digitate vessel endings, unaccompanied by phloem, present at the boundary between the palisade and spongy mesophyll of *Leptadenia lancifolia* Decne. according to Trochain (2280). Both solitary and clustered **crystals** occur. Sphaerocrystals of calcium phosphate recorded in spirit material of *Ceropegia* and *Stapelia*. **Fat bodies** present in the mesophyll of species of *Morrenia*. **Secretory cells** filled with a yellow substance recorded by Solereder in the mesophyll of *Solenostemma argel* Hayne, and cells with tanniniferous contents near the veins of *Pentatropis cynanchoides* R. Br. by Sabnis (1977). **Laticiferous canals** accompany the vascular bundles throughout the family, sometimes with branches extending into the mesophyll in species of *Araujia*, *Asclepias*, *Daemia*, *Dischidia*.

The **pitcher-like leaves** of *Dischidia rafflesiana* Wall. represent a biological specialization. There is no evidence to suggest that they possess any carnivorous function, but, according to Scott and Sargant (2067), serve rather for the accumulation of detritus, and for the collection of condensed water. They represent leaves which have become modified 'by great intercalary growth of the whole region between the petiole and apex, the morphologically upper surface growing more rapidly than the lower. The outer surface of the pitcher therefore represents the upper surface of the leaf, and the inner surface of the pitcher the lower surface of the leaf.' The stomata are more numerous on the inside than on the outside of the pitcher. For other details concerning leaf structure see under 'Ecological Anatomy'.

AXIS

YOUNG STEM (Fig. 213 D)

Cork arising superficially, usually in the epidermis or sub-epidermis; the component cells mostly tabular and thin-walled, but thickened in species of *Cynanchum* and *Periploca*. Primary **cortex** containing varying amounts of collenchyma, and sometimes palisade or spongy assimilatory tissue. Stone cells also frequent in this tissue, sometimes forming a ring, e.g. in *Hoya*. Sclerenchymatous fibres recorded by Solereder in the cortex of *Sarcostemma viminale* R. Br. and scattered groups of stone cells by Sabnis (1977) in the corresponding position in *Sarcostemma brevistigma* Wight et Arn. **Endodermis** usually conspicuous. **Pericycle** generally broad; usually containing solitary or grouped fibres, commonly with unlignified walls, but slightly lignified walls noted in *Vincetoxicum*. A ring of stone cells sometimes present on the inside of the pericycle in species of *Leptadenia*, *Periploca*, *Sarcostemma*.

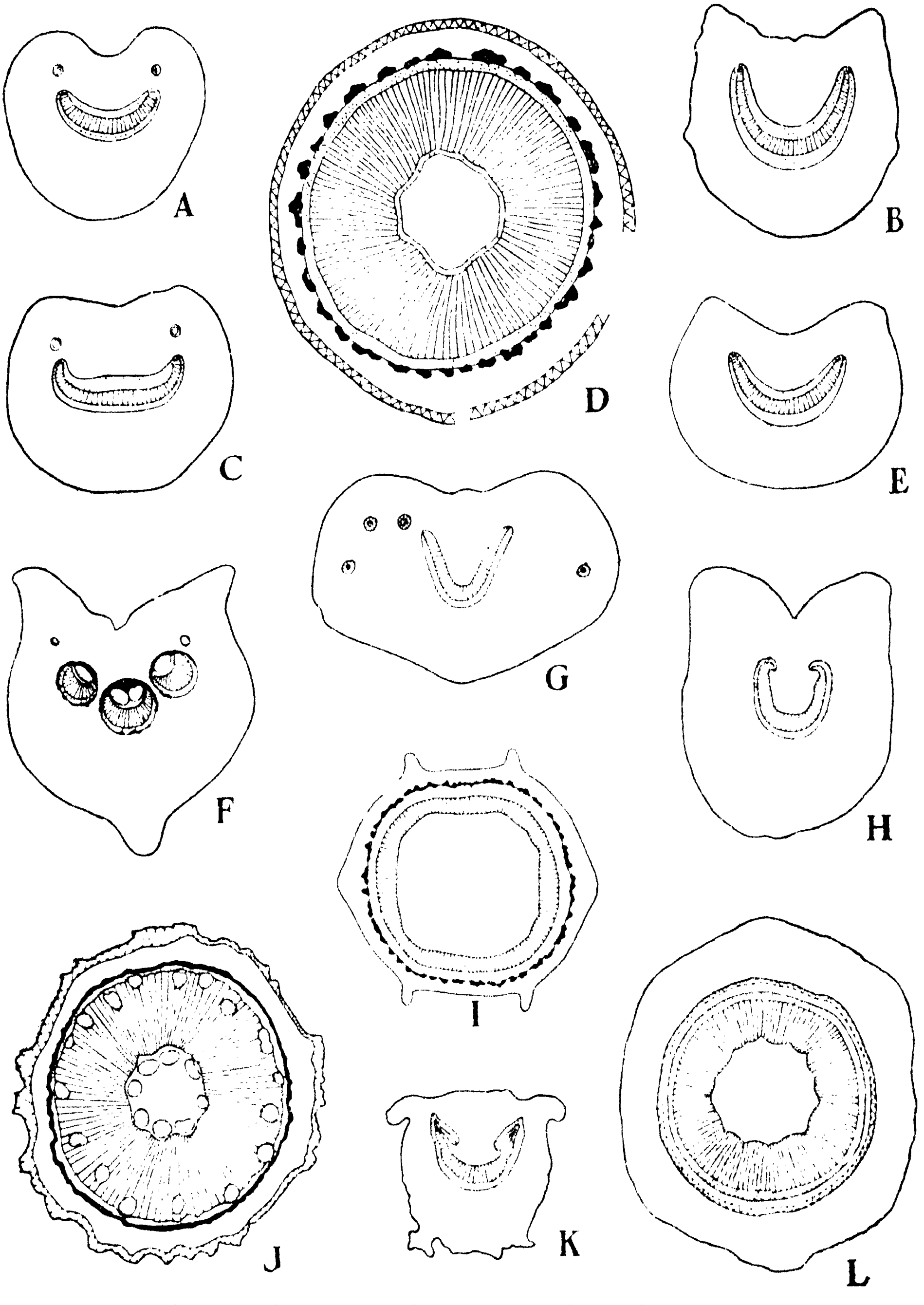


FIG. 213. *ASCLEPIADACEAE*, A–E; *LOGANIACEAE*, F–L

A, *Vincetoxicum officinale* Moench. Petiole × 15. B, *Chlorocodon whitei* Hook. f. Petiole × 19. C, *Marsdenia erecta* R. Br. Petiole × 19. D, *Asclepias curassavica* Linn. Stem × 15. E, *A. curassavica* Linn. Petiole × 19. F, *Strychnos nux-vomica* Linn. Petiole × 19. G, *Desfontainia spinosa* Ruiz. et Pav. Petiole × 19. H, *Nicodemia diversifolia* Tenore. Petiole × 19. I, *Buddleia globosa* Hope. Young stem × 9. J, *Strychnos nux-vomica* Linn. Stem × 19. K, *Buddleia paniculata* Wall. Petiole × 19. L, *Desfontainia spinosa* Ruiz. et Pav. Stem × 19.

Secondary **phloem** containing chambered crystal-fibres in species of *Gymnema* and *Periploca*. **Xylem** in the form of a continuous cylinder traversed by narrow rays in all of the species examined at Kew, but species with broad primary rays also occur; vessel perforations simple. **Intraxylary phloem** universally present at the periphery of the pith, either in the form of separate strands or as a continuous ring. The structure and mode of development of the intraxylary phloem have been described by Handa (884) for *Marsdenia tomentosa* Decne. Some of the intraxylary phloem in old stems of *Leptadenia* is produced centripetally from a cambium according to Balwant Singh (118). Intraxylary phloem is sometimes accompanied internally by fibres in species of *Calotropis*, *Gomphocarpus*, *Periploca*. Phloem also stated to occur more deeply seated in the pith in a few species of *Ceropegia*, *Kanahia*, and *Stephanotis*. **Pith** containing large intercellular spaces in species of *Araujia*, *Gomphocarpus*, *Periploca*; stone cells in species of *Astephanus* and *Hoya*; sclerenchymatous fibres in species of *Cryptolepis* and *Cryptostegia*.

Laticiferous canals present in all examined material, and probably occurring generally throughout the family. **Secretory cells** with tanniniferous contents recorded by Sabnis (1977) in the outer cortex, broad medullary rays and pith of a few species of *Glossonema*, *Leptadenia*, and *Pentatropis*. **Crystals** (see also 'Leaf') either solitary or clustered. Unusual crystals, consisting of a central portion composed of truncated pyramids united at their bases, and accompanied by 2 external pyramids with their bases outwardly directed, recorded by Solereder in the phloem of *Cryptolepis*, *Cryptostegia*, *Periploca*.

For other details concerning stem structure see under 'Ecological Anatomy'.

WOOD (Fig. 212 I–L)

Vessels medium-sized to small, except in the lianes; often with extremely small, tracheid-like groups associated with the larger vessels; in radial flames (dendritic) in *Periploca* (Fig. 212 I) and, in the first annual ring at least, in some species of *Asclepias*, *Cryptolepis*, and *Tacazzea* and with numerous multiples of 4 or more cells in *Calotropis*; ring-porous in *Periploca*. Perforations simple. Intervascular pitting alternate and rather large; vestured (78); pits to ray cells similar. Mean member length 0·2–0·26 mm. **Parenchyma** predominantly apotracheal in *Periploca*, as scattered cells tending to form numerous, short, irregular lines (Fig. 212 I); usually sparse in the other genera and associated with the vessels (Fig. 212 L); described by Messeri (1493) as vasicentric and diffuse in *Calotropis*. Strands mostly of 2–4 cells; storied and often fusiform in *Leptadenia*. **Rays** typically narrow, less than 4 cells wide, except for a few wide and high rays in *Periploca* and the large primary rays in some climbers, e.g. *Leptadenia*; less than 1 mm. high; about 15–20 per mm.; heterogeneous with 5–10 marginal rows of upright cells in *Calotropis*; sometimes composed entirely of upright cells (2158); the smaller rays in *Leptadenia* and *Periploca* mostly uniseriate, those of the latter almost homogeneous and composed of procumbent cells with occasional rows of square cells; those of the former of square or upright cells only; containing numerous solitary crystals in *Leptadenia*; small rays storied in *Leptadenia* and *Periploca*. **Fibres** with small bordered pits that are equally numerous on both radial and tangential walls, e.g. in *Leptadenia* and *Cryptolepis*, or with the pits simple or with only minute borders and more numerous on the radial than on the tangential walls, e.g. in *Periploca* and *Sarcostemma* (2158); with thin walls; mean length 0·3–0·75 mm. **Vasicentric** and **vascular tracheids** present in *Leptadenia* and *Periploca* (Fig. 212 I). **Included (interxylary) phloem** of the 'foraminate' type (*c.l. foraminulatum*) present in *Leptadenia lancifolia* Decne., with strands of phloem included in the xylem (Fig. 212 L). (See also under 'Anomalous Structure' below.)

ROOT

Primary **cortex** of the terrestrial roots of *Morrenia odorata* Lindl. containing intercellular spaces filled with mucilage. **Styloids** recorded in the phloem of *Menaba venenata* Baill. The structure and mode of development of the **exodermis** in the root of certain members of the Asclepiadaceae has been described by Francke (709). **Mycorrhiza** in certain members of the family have been investigated by Demeter (562).

ANOMALOUS STRUCTURE

(i) Eccentric or unequal development of the xylem common in climbing species. (ii) Furrowed xylem in *Gymnema sylvestre* R. Br. (iii) Cleavage of wood in *Calotropis*. (iv) Areas of unlignified xylem recorded in species of *Ceropegia* and *Gonolobus*. (v) Islands of **interxylary phloem** recorded by Solereder at the base of the stem and/or in the root of *Asclepias obtusifolia* Michx., *A. syriaca* Linn., and *Ceropegia* sp. The occurrence and centripetal development of interxylary phloem in *Leptadenia* have been described by Balwant Singh (118). (See also under 'Wood', above.)

ECOLOGICAL ANATOMY

The anatomy of the **leafless stems** of various species of *Cynanchum*, *Decanema*, *Drepanostemma*, *Folotsia*, *Mahafalia*, *Prosopostelma*, and *Sarcostemma* from Madagascar has been investigated by Puech (1761). The structure conforms with that of the rest of the family in exhibiting cellulose fibres in the pericycle, and in showing continuous cylinders of phloem and xylem traversed by narrow rays, as well as intraxylary phloem and laticiferous canals. In addition many of these leafless species include a varying proportion of cellulose fibres in the cortex, especially towards the interior. In most species the inner part of the cortex shows a somewhat spongy structure. In some species a large proportion of the stem consists of cortical tissue, the vascular cylinder being relatively small, whilst in others the converse is true. Puech claims that the various species can be not only identified but classified on the basis of their stem structure. For this purpose the distribution and frequency of fibres in the cortex, pericycle, and pith, the frequency and distribution of the laticiferous canals and the presence or absence of a clearly defined endodermis were found to be the most valuable characters, and a key to the species based on these features is given in Puech's paper. The outline of the stem in transverse sections was found to be characteristic of certain species, e.g. stellate, owing to the presence of superficial prominences, in '*Cynanchum verrucosum*', ovoid, with depressions in the surface in *C. implicatum* Jumelle et Perr., and with surface depressions with a stoma at the base of each in *Decanema bojerianum* Decne. Other noteworthy features mentioned include the absence of fibres from the cortex of *Cynanchum edule* Jumelle et Perr., but not from the corresponding position in other members of the same genus; the beautiful colour assumed by the latex of *C. macranthum* Jumelle et Perr. when stained with Sudan III; the presence of droplets of oil in the outer part of the cortex of *Mahafalia nodosa* Jumelle et Perr.; the specially broad pericycle including 4 concentric zones of fibre strands in *Prosopostelma madagascariense* Jumelle et Perr.; the extensive lignification of the pith in *Sarcostemma viminale* R. Br., a feature believed to be correlated with soil conditions.

The structure of species of the cactus-like genera *Hoodia*, *Tavaresia*, and *Trichocaulon*, which occur in desert regions in South-West Africa, has been investigated by Zemke (2505). The vegetative body of *Trichocaulon* is a slightly elongated bulbous structure, bearing leaves which are reduced to whorls of slightly enlarged, hexagonal cushions. *Hoodia* and *Tavaresia* are somewhat similar in structure, but bear thorns which are attached to the leaf rudiments. In *Hoodia* the thorns are seated on the parenchymatous tissue of the leaf-cushions but separated from it by 2 layers of cells. The epidermis in all 3 genera consists of remarkably small cells, the outer walls of which are slightly cutinized in *Tavaresia* and *Trichocaulon* but more strongly cutinized in *Hoodia*. The stomata are not sunken. Transverse sections of all 3 genera are essentially similar in appearance, but the following description applies especially to *Tavaresia*. There is a circle of bicollateral vascular bundles supported externally by massive fibre strands, whilst small leaf traces pass outwards through the broad cortex from the main vascular ring. The cortex is also supported by numerous strands of fibres. Assimilatory tissue is restricted to the outer part of the cortex which consists of palisade tissue. The spongy pith includes numerous intercellular spaces. Narrow, thin-walled, unsegmented laticiferous tubes occur in the pith, and, in *Tavaresia*, in the cortex as well. There is a well-developed endodermis containing starch in *Hoodia*.

Zemke compares *Hoodia*, *Tavaresia*, and *Trichocaulon* with *Caralluma*. The last genus is also fleshy, but bears decussately arranged leaf-like organs, each terminating in a thorn. The internal structure is similar to that of the 3 genera already described, and the cells of the epidermis are only slightly cutinized. Numerous cells with fatty contents were noted in the pith near the vascular bundles.

An anatomical comparison of the leaf of a xerophytic and mesophytic leaf of *Asclepias syriaca* Linn. made by Starr (2188) showed the xerophyte to be characterized by hairs on both surfaces (confined to the lower side in the mesophytic form); cells of the upper epidermis taller but wider; palisade deeper in proportion to the spongy tissue or a second palisade layer partly organized; latex and other secretions more abundant.

Taxonomic Notes

The rather outstanding anatomical similarities between the Apocynaceae and Asclepiadiaceae confirm that these 2 families are closely related.

Economic Uses

Fibres are obtained from the stems of various members of the family, but none of them are of any great economic importance, although Yercum or Madar Fibre, derived from the bark of *Calotropis gigantea* R. Br., is of local importance in India. Various unsuccessful attempts have been made to cultivate American Milkweed (*Asclepias incarnata* Linn.) for the production of fibre, whilst the floss attached to the seeds of the same species has also aroused interest from time to time. The structure and physical properties of the floss of *Asclepias syriaca* Linn. have been investigated by Dischendorfer (591). During the Second World War the rubber content of various species of *Asclepias* was reinvestigated, but it was not used in commercial quantities. More success was obtained with the rubber from *Cryptostegia grandiflora* R. Br. which was cultivated in India and other countries. The anatomy of this plant has been investigated by Blaser (206), who showed that there is a branching system of unarticulated laticiferous canals in the embryo. In the seedling the canals are situated mainly in the cortex, but there are extensions into the pith through gaps associated with the cotyledonary traces. In young stems the laticiferous canals in the cortex and pith are interconnected through the foliar gaps, but during secondary thickening the connecting links become embedded. In the leaf, some of the laticiferous elements pass out from around the veins and extend for some distance along the inner surface of the epidermal cells.

Condurango Bark, obtained in Ecuador from *Marsdenia condurango* Nichols, is used medicinally in gastric complaints. It occurs in pieces 5–10 cm. long and 2–6 mm. thick, and is characterized microscopically by prismatic crystals in the phelloderm, and cluster crystals in the other tissues; abundant laticiferous canals; simple or compound starch grains in the outer tissues; clusters of pitted stone cells in the cortex and phloem.

Indian Sarsaparilla derived from *Hemidesmus indicus* R. Br. was at one time used as a substitute for *Sarsaparilla* derived from *Smilax* spp. (Family Liliaceae).

According to Lendner (1358) the leaf of *Solenostemma argel* Hayne has been used as a substitute for Senna (see p. 500). The adulterant may be recognized by the branched, laticiferous canals in the ground tissue of the petiole and by the characteristic cluster crystals of calcium oxalate.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Araujia, Asclepias,* Astephanus, Calotropis, Caralluma, Ceropegia, Chlorocodon,* Cryptolepis, Cryptostegia, Cynanchum, Daemia, Decanema, Dischidia, Drepanostemma, Folotsia, Glossonema, Gomphocarpus,* Gongronema, Gonolobus, Gymnema, Hemidesmus, Hoodia, Hoya, Kanahia, Leptadenia, Mahafalia, Marsdenia,* Menabea, Morrenia, Pentatropis, Pergularia, Periploca,* Prosopostelma, Sarcostemma, Solenostemma, Stapelia, Stephanotis, Tavaresia, Trichocaulon, Tylophora, Vincetoxicum.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

(Asclepias), (Calotropis), (Cryptolepis), (Gymnema), Leptadenia, Periploca, (Sarcostemma), (Tacazzea).

LITERATURE

(i) *On General Anatomy*

Balwant Singh **118**, Blaser **206**, Dastur and Saxton **543**, Demeter **562**, Dischendorfer

591, Francke 709, Glabisz 788, Handa 884, Lendner 1358, Pfeiffer 1709, Puech 1761, Sabnis 1977, Sayeedud-Din and Suxena 2017, Scott and Sargant 2067, Starr 2188, Trochain 2280, Zemke 2505.

(ii) *On Wood Structure*

Bailey 78, Messeri 1493, Pfeiffer, H. 1712, Record 1843, 1851.

191. LOGANIACEAE

(FIG. 213 on p. 920; FIG. 214 on p. 926; FIG. 215 on p. 930)

SUMMARY

(i) GENERAL

A tropical and sub-tropical family consisting mostly of woody plants, although a few herbs are included. It comprises 2 clearly defined groups or sub-families, the Buddleioideae and Loganioideae. These 2 divisions, which, by some taxonomists such as Wettstein (2416), have been treated as separate families, may be recognized by the anatomy of their vegetative organs as well as by floral and other characters. **Intraxylary phloem** is always present in the axis of the Loganioideae, whereas this tissue is absent from the Buddleioideae. Then again the **cork** is usually superficial in the Loganioideae and pericyclic in the Buddleioideae, although exceptions are known to occur. Stellate or candelabra **hairs,** sometimes intermixed with small scales, are widely distributed amongst the Buddleioideae but not amongst the Loganioideae, and glandular hairs are confined to the Buddleioideae. The **stomata** are surrounded by a variable number of distinct and variously orientated subsidiary cells in some species or by ordinary epidermal cells in others. Quite a number of genera are characterized by a mucilaginous layer on the inside of the upper epidermis or, less commonly, by mucilaginous cells in the mesophyll. Other important characters include the presence of **hypoderm** and branched sclerenchymatous idioblasts in the mesophyll and/or ground tissue of the axis, as well as the occurrence of **interxylary phloem.** The somewhat anomalous genera *Desfontainia* and *Plocosperma* are described separately.

(ii) WOOD

Vessels very variable in size and number, often with numerous multiples of 4 or more cells, sometimes with dendritic or ulmiform arrangement, occasionally ring-porous and with spiral thickening, perforations simple, intervascular pitting alternate, usually small to minute, but occasionally moderately large, vestured, pits to ray cells usually similar; members of medium length. **Parenchyma** very variable; absent, a few cells to a distinct sheath round the vessels, or in narrow or broad bands. **Rays** (*a*) exclusively uniseriate, short to high, most commonly of high upright or square cells with intercellular spaces; (*b*) up to 3–12 cells wide, usually with rather short or few uniseriates, often more than 1 mm. high, heterogeneous to almost homogeneous. **Fibres** septate in a few genera, in the others with simple or small bordered pits, of medium length. **Included phloem** of the 'foraminate' type present in 4 genera.

LEAF

Usually dorsiventral; rarely isobilateral in *Gomphostigma*, *Logania*, *Nuxia*, *Strychnos*. Centric leaves with the palisade tissue much reduced, described by Holm (1010) for *Polypremum procumbens* Linn. Simple, unicellular or uniseriate **hairs** occur in the Loganioideae, but none recorded in the Buddleioideae. Stellate or candelabra hairs (Fig. 214 B–D) widely distributed amongst the Buddleioideae; sometimes intermixed with small scales (Fig. 214 E). Glandular hairs with flattened heads divided by vertical walls into 2, 4, or more cells generally occurring in the Buddleioideae (Fig. 214 A). Tufts of unicellular hairs, inserted on a multicellular pedestal, characteristic of the *Tomentosae* section of *Spigelia*. Short-stalked, glandular, shaggy hairs with ellipsoidal heads, each having a multiseriate central group of cells enclosing solitary crystals, and surrounded by a 1-layered sheath of secretory palisade cells, occur at the base of the leaf or petiole in species of *Fagraea* and *Strychnos*. **Extra-floral nectaries,** each consisting of a lobed pit-like depression, lined with palisade-epithelium and communicating with the exterior by a minute aperture, occur on both surfaces of the lamina, at the base of the petiole and on the stem below the stipules in a number of species of *Fagraea*. **Cork warts** recorded on the lower surface in species of *Anthocleista* and *Fagraea*. **Epidermis** composed of cells with straight or sinuous anticlinal walls. Inner walls of the cells of the upper epidermis provided with muci-

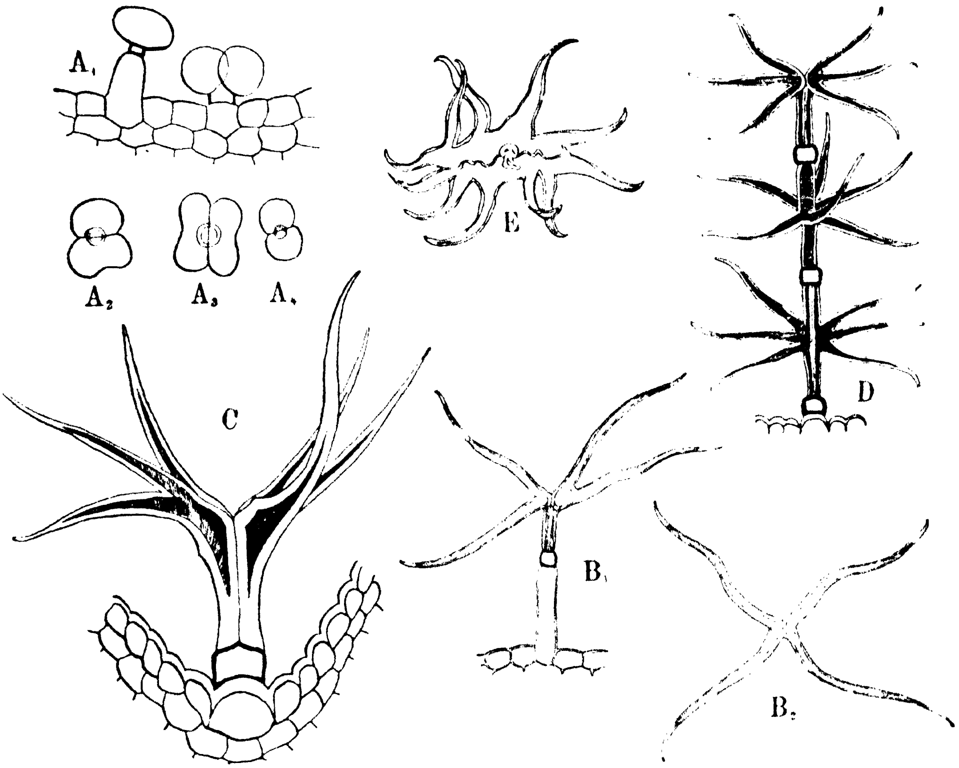


FIG. 214. *LOGANIACEAE*

A_1–A_4, Glandular hairs of *Buddleia americana* L.: A_1, in transverse section, A_2–A_4, in surface view; B_1–B_2, 4-armed stellate hair of the same species: B_1, seen from the side, B_2, in surface-view; C, 6-rayed stellate hair of the same species. D, Candelabra-hair of *Buddleia salviaefolia* Lam. E, Peltate hair of *Gomphostigma scoparioides* Turcz.—By Solereder.

laginous thickenings in species of *Coinochlamys*, *Logania*, *Mitrasacme*, *Mostuea*. Papillae rarely present on the upper epidermis of *Adenoplea* and *Buddleia*, and on the lower epidermis in species of *Logania* and *Strychnos*. **Hypoderm** recorded in species of *Anthocleista*, *Bonyunia*, *Couthovia* (common on both sides), *Fagraea*, *Geniostoma*, *Labordia* (common both sides), *Norrisia*, *Nuxia*, *Peltanthera*, *Strychnos*. **Stomata** variable; cruciferous in most of the genera; rubiaceous in species of *Gelsemium* and *Strychnos*; ranunculaceous types also recorded. Stomata usually confined to the lower side, but sometimes occurring on both surfaces in species with isobilateral leaves. **Mesophyll** including cells with partly mucilaginous walls in the spongy tissue in species of *Geniostoma* and *Mitrasacme*. Fatty bodies frequent in the assimilatory tissue. Sclerenchymatous idioblasts (see also under 'Axis') recorded in the mesophyll of species of *Anthocleista*, *Fagraea*, *Potalia* with thick, fleshy leaves, and somewhat branched stone cells in species of *Strychnos*. Vascular bundles of the **veins** surrounded by little or no sclerenchyma except in species of *Strychnos*. Bundles of the larger veins of some species of *Strychnos* bicollateral, but appearing to be inversely orientated in others owing to suppression of the normal phloem and to the continued development of the intraxylary phloem. **Petiole** (Fig. 213 F, G, H, K), in transverse sections through the distal end, exhibiting a U-shaped, median vascular strand, accompanied by smaller accessory bundles in the wings in *Buddleia globosa* Hope and *Nicodemia diversifolia* Tenore (Fig. 213 H); structure somewhat similar but median strand wider, shallower, and provided with inwardly directed ends in *Buddleia paniculata* Wall. (Fig. 213 K). Petiole of *Strychnos nux-vomica* Linn. (Fig. 213 F) supplied by an arc of about 3 bicollateral bundles, each provided with interxylary phloem towards the adaxial side and strongly supported by sclerenchyma in the pericyclic region; smaller accessory bundles present in the wings. **Crystals** of various kinds present in the family, several types sometimes occurring together in a single species. Large cluster crystals present in idioblasts in the mesophyll in species of *Strychnos* and *Usteria*; similar crystals in the veins of *Strychnos martii* Prog. and *S. parvifolia* A. DC., serve to distinguish these from other, closely related species. Large solitary crystals rare except in *Strychnos* and a few species of *Gardneria* and *Mostuea*. Small or minute solitary crystals recorded in species of *Adenoplusia*, *Geniostoma*, *Labordia*, *Polypremum*; small acicular crystals common in *Anthocleista*, *Buddleia*, *Chilianthus*, *Fagraea*, *Gomphostigma*, *Logania*, *Nuxia*, *Peltanthera*, *Potalia*, *Spigelia*. Crystal-sand characteristic of *Couthovia*. V-shaped crystals, recognizable under a lens as transparent dots, recorded in a number of closely related species of *Strychnos* (*S. brasiliensis* Mart. *et al.*).

AXIS

YOUNG STEM (Fig. 213 I, J)

Sometimes ribbed, e.g. in *Buddleia globosa* Hope (Fig. 213 I). Ribbed stems of xerophilous species of *Spigelia* provided with sub-epidermal groups of sclerenchyma together with palisade tissue in the primary cortex. **Cork** superficial in origin in all investigated species of *Anthocleista*, *Couthovia*, *Fagraea*, *Geniostoma*, *Labordia*, *Logania*, *Norrisia*, *Peltanthera*, *Polypremum*, *Spigelia*, *Strychnos*; arising in the pericycle in all investigated species of *Adenoplusia*, *Buddleia*, *Chilianthus*, *Emorya*, *Gomphostigma*, *Nicodemia*, *Nuxia*.

Cork cells with wide lumina and thin or thick walls; sclerosed on 1 side only in species of *Bonyunia*, *Geniostoma*, *Strychnos*. Cork consisting of lamellae, each composed of 2 or 3 layers of cells, in *Couthovia*, *Geniostoma*, *Labordia*. Stone cells present in the cork of *Fagraea*. Middle or inner part of the primary **cortex** of most species of *Strychnos* including a ring of stone cells, but these elements are absent from a small group of species in the same genus (for further details see Solereder). Stone cells also said to occur in the primary cortex of a few species of *Geniostoma*, *Labordia*, *Logania*, *Spigelia*, and sclerenchymatous idioblasts in species of *Anthocleista*, *Fagraea*, and *Potalia*. **Pericycle** containing groups of rod cells in species of *Fagraea*, *Labordia*, *Nicodemia*, *Peltanthera*; including a loose ring or isolated strands of fibres in species of *Adenoplusia*, *Buddleia*, *Chilianthus*, *Couthovia*, *Fagraea*, *Gardneria*, *Gelsemium*, *Geniostoma*, *Gomphostigma*, *Labordia*, *Logania*, *Mitreola*, *Nuxia*, *Polypremum*, *Potalia*, *Spigelia*, *Strychnos*; devoid of sclerenchyma in species of *Anthocleista*, *Bonyunia*, *Coinochlamys*, *Couthovia*, *Fagraea*, *Geniostoma*, *Logania*, *Mitrasacme*, *Mitreola*, *Mostuea*, *Norrisia*, *Strychnos*. **Xylem,** in the few species of *Buddleia*, *Nicodemia*, and *Strychnos* examined at Kew, in the form of a continuous cylinder traversed by narrow rays, but species with wide primary rays also occur. Similar structure recorded in *Fagraea* by Hasselberg (918). Vessels mostly with simple perforations, but occasional scalariform plates also recorded (see 'Wood'). Tertiary spiral thickening noted in the vessels in some species of *Buddleia* and *Nicodemia*. **Interxylary phloem** sometimes present, e.g. in *Strychnos* (Fig. 213 J). (See also under 'Wood'.)

Pith often wholly parenchymatous, but including groups of stone cells in species of *Strychnos*, elongated, sclerenchymatous cells in *Couthovia*, *Gardneria*, *Spigelia*, *Usteria*, and sclerenchymatous idioblasts in species of *Anthocleista*, *Fagraea*, *Potalia*. **Medullary** and **cortical bundles** recorded by Solereder in *Anthocleista*, those in the cortex being centric with central xylem. Cortical leaf trace bundles recorded, and their course described in detail, in various species of *Fagraea* by Hasselberg (918). A ring or isolated bundles of **intraxylary phloem** (Fig. 213 J) always present in the Loganioideae, but absent from the Buddleioideae; sometimes becoming enlarged by cambial activity or, in *Gelsemium*, converted to inversely orientated medullary bundles through the activity of a cambium. **Crystals** (see also under 'Leaf'). Solitary crystals noted in the cortex and phloem and druses in the cortex and pith of *Strychnos nux-vomica* Linn. Styloids accompanied by cluster crystals recorded in the primary cortex and/or phloem of *Usteria*, as well as in the intraxylary phloem of *Bonyunia*. **Secretory elements.** None seen in the material examined at Kew.

Wood (Fig. 215)

Vessels very variable in size, very small (25–50 μ mean tangential diameter) in some of the species of *Buddleia*, *Chilianthus*, and *Strychnos* (medium-sized in the liane species) and largest (about 200 μ) in *Anthocleista* and *Fagraea*; sometimes with numerous radial multiples of 4 or more cells, e.g. in species of *Antonia*, *Bonyunia*, *Buddleia*, *Norrisia* (Fig. 215 D), and *Strychnos* and sometimes with a few clusters; often with a marked flame-like or dendritic grouping of the vessels (Fig. 215 E) in the tree and shrub species of *Strychnos* from Africa and Asia, e.g. in *S. arborea* Hill, *S. atherstonei* Harv., *S. mitis*

Moore, and *S. potatorum* L.; Cockrell (436) found this character in only 2 out of the 26 South American species he examined, most of which were lianes. With a tendency to a tangential pattern in *Buddleia* p.p.; 1–80 per sq. mm., fewer than 5 per sq. mm. in *Anthocleista, Couthovia,* and *Fagraea,* and 40 or more per sq. mm. in *Buddleia, Chilianthus,* and *Lachnopylis*; with a tendency to be ring-porous in some species of *Buddleia, Chilianthus,* and *Couthovia*; spiral thickening observed in *Chilianthus* and reported by Solereder in *Gomphostigma, Lachnopylis, Logania,* and *Nicodemia.* Perforations typically simple, but Solereder has noted occasional scalariform plates, with few bars or malformed perforations, in species of *Geniostoma, Labordia,* and *Mitreola.* Intervascular pitting alternate, most commonly very small to minute, but sometimes moderately large, e.g. in *Anthocleista, Chilianthus,* and *Fagraea*; vestured (78); pits to ray and wood parenchyma similar to the intervascular pitting, except in *Fagraea,* in which they are commonly elongated and simple. Tyloses common in *Fagraea,* sometimes pitted. Mean vessel length 0·32–0·9 mm. **Parenchyma** very variable; lacking from or very rare in *Antonia, Bonyunia, Buddleia,* and *Chilianthus*; predominantly paratracheal, with a few cells to a complete sheath round the vessels in *Geniostoma, Lachnopylis* (Fig. 215 A), and *Norrisia*; in broad bands in *Anthocleista, Fagraea* (Fig. 215 H), and, according to Record (1855), *Potalia,* and in numerous, uniseriate irregular bands in *Couthovia*; terminal bands sometimes present, e.g. in *Strychnos.* Containing chambered crystals in some species of *Strychnos* and crystal-sand in *Couthovia.* Strands usually of 4 cells. In some species of *Fagraea,* e.g. *F. fastigiata* Bl. and *F. gigantea* Ridl., the parenchyma is of an unusual type, consisting of fusiform cells, each divided in the middle by a septum; these may be distributed as scattered cells, narrow bands or sheaths round the vessels. **Rays** (*a*) exclusively uniseriate or with only occasional biseriate parts in *Anthocleista, Antonia, Bonyunia, Couthovia, Fagraea, Norrisia,* and *Potalia* (1855); the rays commonly more than 1 mm. high, composed of large square or upright cells and with numerous intercellular spaces in *Anthocleista, Couthovia,* and *Fagraea,* similar but shorter in *Antonia, Bonyunia,* and *Norrisia* and composed of procumbent cells in the latter and in *Antonia*; 13–18 rays per mm. Fusiform rays containing radial strands of phloem present in *Antonia, Bonyunia, Norrisia,* and a few species of *Strychnos* (436); according to Cockrell (436) these are essentially radial proliferations from the outer margins of the vertical phloem strands. Record (1834) notes that 'some of the rays contain open intercellular canals . . .' in *Anthocleista nobilis* G. Don. (*b*) The larger rays up to 3–12 cells wide in *Buddleia, Chilianthus, Geniostoma, Nuxia,* and *Strychnos,* and, according to Solereder, up to not more than 3 cells wide in *Anthocleista inermis* Engl.; commonly more than 1 mm. high; uniseriate rays moderately numerous, but often low, and composed almost entirely of upright cells, but very few in some species of *Chilianthus* and *Strychnos*; 7–17, mostly 7–11 rays per mm.; typically heterogeneous (Kribs's Type II A), with 1–3 marginal rows of square or upright cells, but commonly with more than 4 rows in *Geniostoma* and some species of *Strychnos*; almost homogeneous in other species of *Strychnos,* e.g. *S. nux-vomica* L.; with sheath cells in some species of *Buddleia, Geniostoma,* and *Lachnopylis.* Groups of 3 or 4 chambered crystals common in *Strychnos.* **Fibres.** Septate fibres observed in *Geniostoma* and *Nuxia,* and occasionally in some species of

Fagraea; Solereder records septate fibres also in *Coinochlamys*, *Labordia*, *Nicodemia*, and *Peltanthera*, and Janssonius (1154) in *Buddleia* p.p. Pits usually simple, but small bordered pits observed in some species of *Antonia*, *Bonyunia*, and *Strychnos*, and reported by Solereder in species of *Couthovia*, *Gelsemium*, *Mostuea*, *Norrisia*, *Polypremum*, and *Usteria*. Walls usually moderately thin, but sometimes very thick, e.g. in *Chilianthus* and *Potalia* (1855) and in most species of *Fagraea* and *Strychnos*. Mean length 0·9–1·7 mm. **Included (interxylary) phloem** of the 'foraminate' type (*c.l. foraminulatum*) present in *Antonia*, *Bonyunia*, *Logania* (2158), *Norrisia*, and *Strychnos*, with circular to oval strands of included phloem surrounded by narrow sheaths of parenchyma and either isolated or linked together by terminal ('initial') parenchyma. Cockrell (436) gives a detailed account of this feature in 26

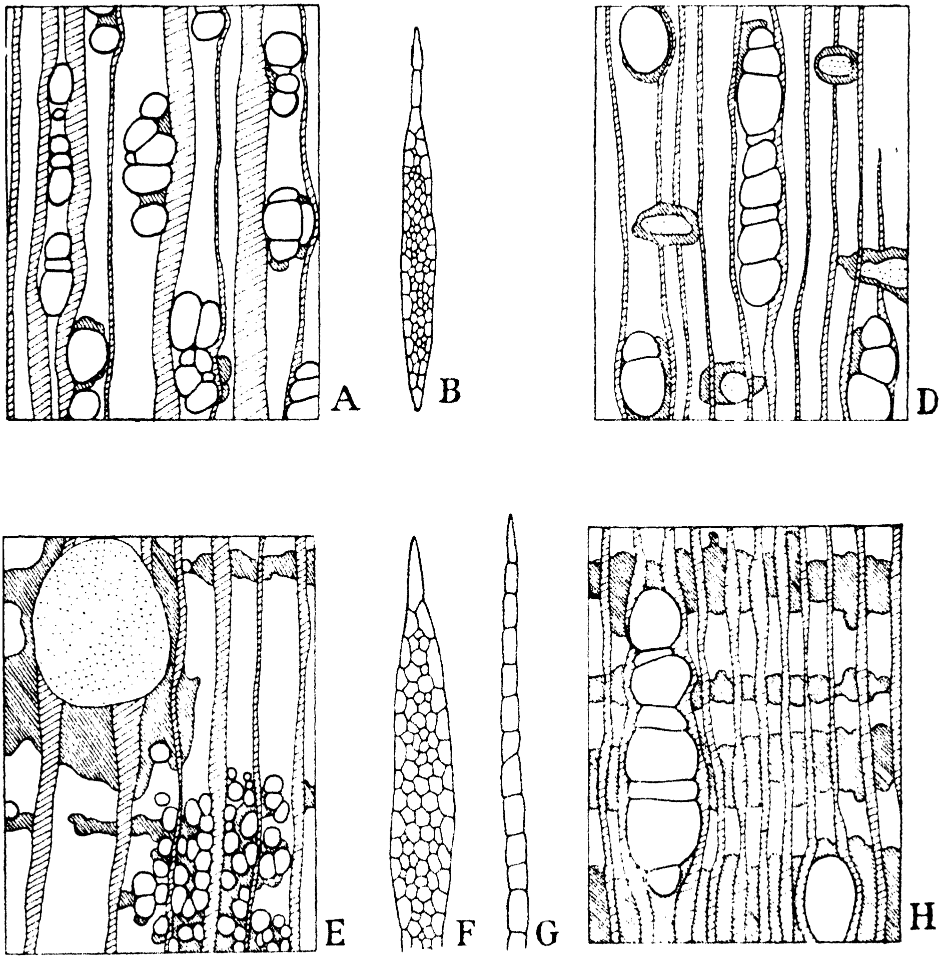


FIG. 215. *LOGANIACEAE*

A, *Lachnopylis floribunda* Benth. B, *Buddleia paniculata* Wall. C, *Bonyunia aquatica* Ducke. D, *Norrisia malaccensis* Gardn. E, *Strychnos atherstonii* Harv. F, *Lachnopylis floribunda* Benth. G, *Anthocleista parviflora* Baker. H, *Fagraea maingayi* C. B. Clarke.

South American species of *Strychnos*. He notes that in addition to this type of anomaly, *S. jobertiana* Baill. has a peculiar radially segmented structure owing to bands of stone cells that are produced in conjunction with radial phloem strands originating close to the pith.

ANOMALOUS STRUCTURE

For intraxylary phloem see under 'Young Stem' and for interxylary or included phloem under 'Wood'.

ANOMALOUS GENERA

DESFONTAINIA

(Description based on *D. spinosa* Ruiz. et Pav. cultivated at Kew)

Leaf dorsiventral. **Stomata** ranunculaceous. **Petiole** (Fig. 213 G) in transverse sections through the distal end, exhibiting a V-shaped median vascular strand with outwardly curved tips to the ends, and accompanied by small accessory bundles in the cortical region. **Cork** (Fig. 213 L) arising in the region of the phloem from successive rings of specially large cells. Primary **cortex** containing isolated stone cells. The **xylem** in young stems consists, for the most part, of radial rows of thin-walled vessels and tracheids of small diameter, separated by predominantly uniseriate rays. Vessels with scalariform perforation plates. Tracheids not easily distinguishable from vessels in transverse sections, but their true nature revealed in macerated material; provided with bordered pits; ends rather abruptly pointed. **Pith** parenchymatous.

PLOCOSPERMA

(Based on *P. buxifolium* Benth. and *P. macrophyllum* Baill.)

Leaf dorsiventral. **Hairs** in the form of (i) simple, unicellular trichomes filled with calcium carbonate and accompanied by cystoliths in the adjacent epidermal cells at the base; (ii) bicellular, club-shaped glandular hairs. **Stomata** ranunculaceous. Vascular bundles of the **veins** provided with a sclerenchymatous sheath and accompanied by cluster crystals. Styloids said to occur in the axis.

TAXONOMIC NOTES

(i) FROM GENERAL ANATOMY

It is interesting to note that the possession of intraxylary phloem by the Loganioideae sharply distinguishes this tribe from the Buddleioideae in which intraxylary phloem is unknown.

(ii) FROM WOOD STRUCTURE

The woods of this family are very varied and suggest more than one distinct group. The Antonieae and Fagraeae of the Loganioideae, for example, seem to be distinct from the other Loganioideae and from the Buddleioideae. The material available for examination was, however, insufficient to justify any more detailed conclusions.

ECONOMIC USES

Many species of *Strychnos* are poisonous and contain alkaloids such as strychnine and brucine. The best-known species is *S. nux-vomica* Linn., which occurs in India and the Malay Archipelago, the seeds being used in medicine as a source of strychnine. The seeds of other species of *Strychnos* are sometimes substituted. St. Ignatius Beans, which possess properties similar to those of nux-vomica, are the seeds of *S. ignatii* Berg. obtained from the Philippine Islands.

The rhizome and roots of *Gelsemium sempervirens* Ait. constitute the drug known as Yellow Jasmine Root, the alkaloids in which relieve neuralgia and similar complaints. The anatomy of *Gelsemium* has been described by Holm (1010) and Tunman (2288). The rhizome can be recognized microscopically by the narrow cortex; the wedge-shaped, bicollateral, vascular bundles with yellow xylem, separated from one another by white medullary rays; prismatic crystals of calcium oxalate up to 30 μ long in the medullary rays where these traverse the phloem; the collenchymatous pericycle. In the root there is, according to Holm (1010), a non-contractile exodermis, and yellow matter in some of the tissues.

The histology of the barks of several species of *Strychnos*, used as tonics or febrifuges in Brazil, has been described by Brocardet (276). It is noteworthy that the internal surface of the bark of *S. pseudo-quina* A. St.-Hil. is, according to Brocardet, coloured red when treated with a drop of fuming nitric acid. The outer surface, when treated in the same way, is coloured green, but rapidly becomes black. Similar reactions are given by the barks of *Rauwolfia bahiensis* A. DC. and a species of *Geissospermum*, both belonging to the Apocynaceae.

This family is not important for its timbers, but Desch (574) notes that some species of *Fagraea* produce timbers that are used locally, e.g. *F. fragrans* Roxb., Burma Yellowheart, and *F. gigantea* Ridl., Tembusu, from Malaya. Scott (2076) states that the South African 'Cape Teak', *Strychnos atherstonii* Harv., is used for wagon work.

Genera Described

(i) For General Anatomy

Adenoplea, Adenoplusia, Anthocleista, Bonyunia, Buddleia,* Chilianthus, Coinochlamys, Couthovia, Desfontainia,* Emorya, Fagraea, Gardneria, Gelsemium, Geniostoma, Gomphostigma, Labordia, Logania, Mitrasacme, Mitreola, Mostuea, Nicodemia,* Norrisia, Nuxia, Peltanthera, Plocosperma, Polypremum, Potalia, Spigelia, Strychnos.*

* Represented in the Kew slide collection.

(ii) For Wood Structure

Anthocleista, (Antonia), Bonyunia, Buddleia, Chilianthus, (Coinochlamys), Couthovia, Fagraea, (Gelsemium), Geniostoma, (Gomphostigma), (Labordia), Lachnopylis, (Logania), (Mitreola), (Mostuea), (Nicodemia), Norrisia, (Peltanthera), (Polypremum), (Potalia), Strychnos, (Usteria).

Literature

(i) *On General Anatomy*

Brocardet **276**, Cockrell and Monachino **438**, Hasselberg **918**, Holm **1010**, **1024A**, Jovet-Ast **1201**, Tunman **2288**, Wettstein **2416**, York **2489**.

(ii) *On Wood Structure*

Bailey 78, Baker 104, den Berger 182, Burgerstein 310, Chalk and Chattaway 362, Cockrell 436, Cockrell and Monachino 438, Cooper and Record 461, Desch 574, Foxworthy 705, Giordano 786, Howard 1088, Janssonius 1154, Kanehira 1206, 1209, Pearson and Brown 1679, Pfeiffer, H. 1712, Record 1834, 1843, 1851, 1855, Record and Hess 1886, Scott 2076, Williams 2430.

192. GENTIANACEAE

(FIG. 216 on p. 934)

A. GENTIANOIDEAE

SUMMARY

Mostly herbs, but including some woody species. The family occurs in temperate and sub-tropical regions. A few of the genera are saprophytic. One of the most outstanding features of the tribe is the universal occurrence of **intraxylary phloem,** by which it is sharply distinguished from the Menyanthoideae where this character does not occur. Strands of phloem more deeply situated in the pith, as well as **medullary bundles,** are also frequent. The **hairs** include bicellular, uniseriate, and glandular shaggy types. The **epidermis** of both leaf and stem is frequently papillose. **Stomata,** ranunculaceous; in the leaf confined to the lower surface, or, less frequently, occurring on both sides. Mucilage cells present in the epidermis and mesophyll of the leaf as well as in the root. In the **petiole** there is usually an arc-shaped, bicollateral strand accompanied by small lateral bundles. The stems of the herbaceous species are commonly provided with **wings.** In the saprophytic species the vascular bundles of the axis exhibit centric structure or transitions between this and bicollateral types. The **endodermis** of the root is particularly well defined, and frequently characterized by radial and tangential divisions of the cells. **Mycorrhiza** are common in the root system.

LEAF

Dorsiventral or isobilateral; mesophyll homogeneous and consisting of horizontally elongated, polygonal cells in *Enicostema* according to Sabnis (1977). **Hairs** infrequent, but uniseriate trichomes with a blunt terminal cell recorded in *Orphium*, and unicellular and bicellular trichomes in *Swertia.* Glandular shaggy hairs present in species of *Bartonia* and *Obolaria.* Upper **epidermis** composed of cells with straight or slightly sinuous anticlinal walls; those of the lower epidermis with sinuous walls. Conical or elongated-cylindrical, frequently striated papillae occur on the epidermis of both leaf and stem in species of *Centaurium*, *Curtia*, *Exacum*, *Gentiana*, *Halenia*, *Hockinia*, *Ixanthus*, *Orphium*, *Purdieanthus*, *Swertia.* For particulars of the structure of the cuticle of the floral leaves in *Centaurium umbellatum* Gilib. see Martens (1448). **Stomata** commonly ranunculaceous, but cruciferous types seen at Kew on both surfaces in *Centaurium umbellatum*; usually confined to the lower side or, less frequently, present on both surfaces, e.g. in *Enicostema* (Sabnis 1977). Stomata present in the saprophytic genera *Cotylanthera*, *Leiphamos*, *Obolaria*, *Voyria* (absent from the axis of these genera). Vascular bundles of the **veins** seldom accompanied by fibres except sometimes in *Deianira* and *Senaea*; larger bundles in *Enicostema* vertically transcurrent by collenchyma and smaller ones embedded according to Sabnis

(1977). **Petiole** not examined in many species; exhibiting an arc of separate bicollateral vascular bundles, in transverse sections through the distal end, in *Exacum affine* Balf. (Fig. 216 A) and species of *Gentiana* (Fig. 216 C) examined at Kew. **Mucilage cells** occur in the epidermis itself or form a definite layer immediately below the upper epidermis in various species of *Gentiana*. The whole mesophyll is more completely mucilaginous in species of *Gentiana*

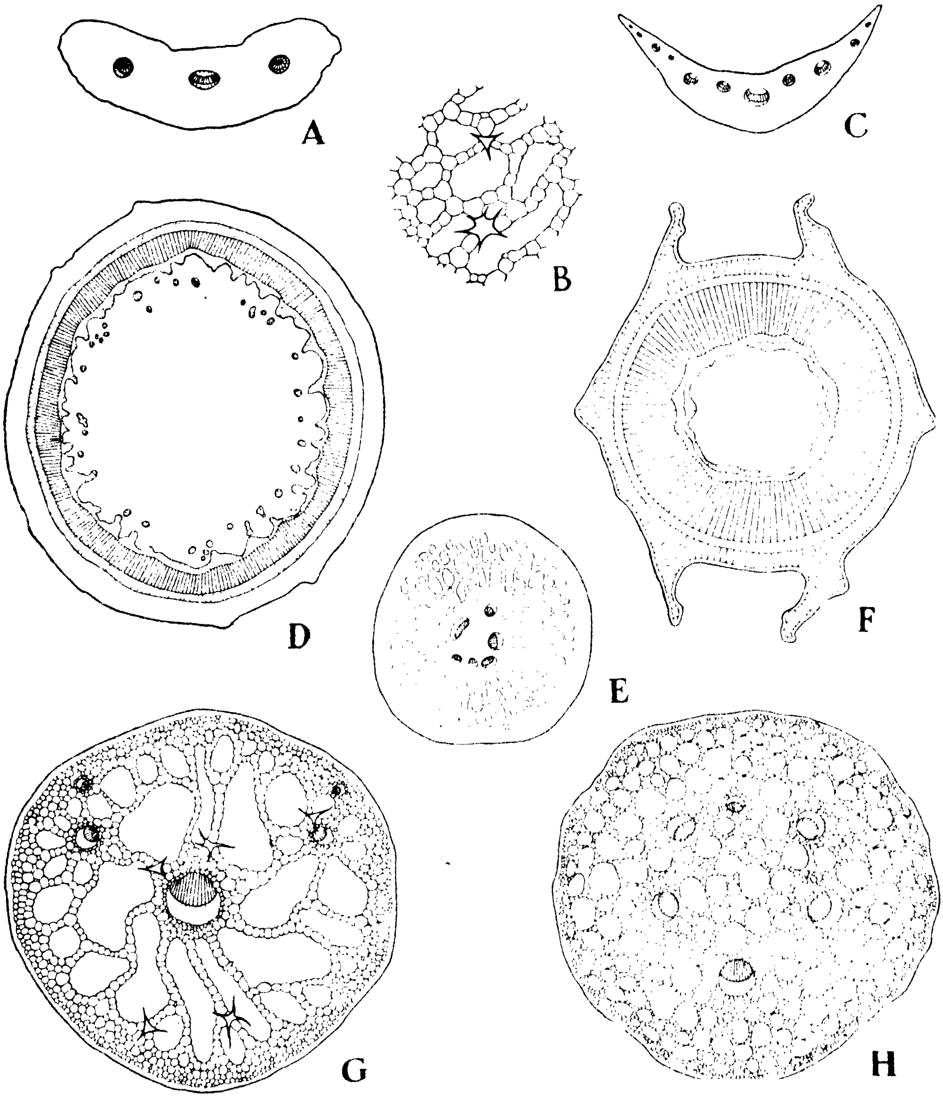


FIG. 216. *GENTIANACEAE*

A, *Exacum affine* Balf. f. Petiole × 18. B, *Limnanthemum peltatum* S. P. Gmel. Stellate idioblasts from cortex of stem × 28. C, *Gentiana trichotoma* Kusnezone. Petiole × 9. D, *G. asclepiadea* Linn. Stem × 18. E, *Limnanthemum peltatum* S. P. Gmel. Stem × 7. F, *Centaurium umbellatum* Gilib. Stem × 31. G, *Limnanthemum peltatum* S. P. Gmel. Petiole × 22. H, *Menyanthes trifoliata* Linn. Petiole × 20.

belonging to the section *Chondrophylla*, endemic to the Himalayas (margins of the leaf cartilaginous in the same section of the genus). Mucilaginous cells also occur in the mesophyll of species of *Belmontia* and *Canscora*. Acicular **crystals,** situated in mucilage cells, recorded in certain species of *Gentiana*; crystal-sand said to occur in the *Chondrophylla* section of the same genus as well as in *Sabbatia*; small clustered crystals recorded in species of *Gentiana, Lehmanniella, Purdieanthus.* Rather large, irregular, crystalline masses noted in some of the cells of *Centaurium umbellatum.* Droplets of oil recorded by Betts (189) in the epidermal cells of *Gentiana corymbifera* T. Kirk.

AXIS

YOUNG STEM (Fig. 216 D and F)

Stems commonly provided with 4 ribs or **wings,** the latter consisting wholly of epidermal cells or containing collenchyma, e.g. in *Enicostema* and species of *Sebaea.* **Epidermis** frequently papillose. Primary **cortex** often lacunar or, sometimes, compressed. **Endodermis** frequently well defined. **Pericycle** generally consisting of thin-walled tissue, often only 1 cell wide; including a few sclerenchymatous elements in species of *Chironia, Deianira, Lagenanthus, Lehmanniella, Lisianthus, Prepusa, Purdieanthus, Rusbyanthus, Senaea, Zonanthus*; sclerenchyma more completely developed in saprophytic genera in compensation for the lack of mechanical support resulting from the reduced amount of xylem. **Xylem** in the form of a closed cylinder with no distinct medullary rays in the few species of *Blackstonia, Centaurium, Exacum,* and *Gentiana* examined at Kew, and, according to Perrot (1691), in other genera and species as well. Uniseriate medullary rays recorded by Sabnis (1977) in *Enicostema.* Xylem of *Gentiana asclepiadia* Linn. and *G. septemfida* Pall., as seen in transverse sections, consisting of 2 distinct concentric zones of equal width, the inner zone being composed of numerous vessels accompanied by a little parenchyma, and the outer zone consisting wholly of fibres. The structure of the xylem of *G. corymbifera* T. Kirk seems to be similar, judging from Betts's (189) description, and it is of fairly general occurrence in the family according to Perrot (1691). Structure tending to be similar, but with the zones not so clearly differentiated in *Blackstonia perfoliata* (L.) Huds. Vessels of *Centaurium umbellatum* Gilib. mostly arranged in radial rows towards the pith, but not very conspicuous through being of about the same diameter as the fibrous elements of the surrounding ground tissue. Only simple perforations in the vessels seen in material examined at Kew. **Phloem** consisting only of small groups of sieve tubes embedded in the xylem ring in species of *Blackstonia, Chironia, Geniostemon, Gentiana, Neurotheca, Schultesia, Swertia.* Outer phloem reduced to a few layers of parenchymatous cells, surrounding small strands of sieve tubes in species provided with a continuous ring of xylem. **Intraxylary phloem** present in all investigated species, occurring in the form of a continuous ring (Fig. 216 F) or as isolated strands on the inside of the vascular bundles (Fig. 216 D). More deeply seated medullary phloem, originating as branches from the intraxylary phloem, present in species of *Bartonia, Centaurium, Cotylanthera, Gentiana, Obolaria.* Medullary phloem tending to become converted to **medullary bundles** in a number of species of *Gentiana.*

Vascular system of the saprophytic genus *Leiphamos* usually consisting of a ring of 4 or 6 centric bundles with central xylem, or of similar bundles tending to be collateral or bicollateral. Bundle system in the form of an almost closed ring in *Cotylanthera*. Semi-saprophytes such as *Obolaria*, as well as the saprophytic genera *Voyria* and *Voyriella*, provided with a bicollateral bundle system, mechanical support being exercised by the xylem. Vascular system of *Bartonia* similar to that of *Obolaria*, but the bundles in the higher internodes varying from collateral to bicollateral. **Pith** in herbaceous species becoming fistular, and the medullary phloem decomposed after the flowering period. Central air canal of *Sabbatia* surrounded by cork. Isolated sclerotic cells rare in the pith, although recorded in *Gentiana pneumonanthe* Linn.; margin of the pith occasionally sclerosed, or the entire tissue becoming sclerosed in *Lehmanniella* and *Senaea*. **Secretory elements** and **crystals** not seen in the material examined at Kew, but stellate clusters of acicular crystals recorded in the cortex and pith of *Enicostema* by Sabnis (1977) and droplets of oil in the epidermal cells of *Gentiana corymbifera* T. Kirk by Betts (189). Sayeedud-Din (2014) observed small cluster crystals in *Enicostema*.

Root

Root hairs generally absent from the saprophytic genera and the smaller species of *Gentiana*. Reduced hairs said to occur in *Cotylanthera*. **Mycorrhiza** present in the root system of the saprophytic genera as well as in species of *Blackstonia*, *Centaurium*, *Gentiana*. **Cork** originating in the pericycle in the few investigated species of *Gentiana*. Primary **cortex** sometimes containing stone cells in *Halenia*. **Endodermis** well defined, consisting at first of tangentially elongated cells, but later becoming divided by from 2 to 20 radial walls in certain species of *Centaurium*, *Crawfurdia*, *Exacum*, *Gentiana*, *Pleurogyna*, *Sebaea*. Tangential division walls also recorded in a few species of *Gentiana* and *Obolaria*. Two endodermal zones separated from one another by a few parenchymatous layers said to occur in a few species of *Swertia*. Endodermal cells apparently remaining undivided in *Belmontia*, *Curtia*, *Microcala*, *Sabbatia*. Primary **vascular structure** nearly always diarch according to Perrot (1691). **Phloem** mainly parenchymatous, but including rather infrequent strands of sieve tissue; becoming very broad in tuberous roots of certain species of *Gentiana* and *Swertia*. **Xylem** wholly lignified in small roots; wholly unlignified, apart from the vessels, in large roots. **Mucilage** recorded in the thick roots of species of *Swertia*, and resinous substances in the cortex of *Gentiana* and *Swertia*.

Anomalous Structure

Interxylary phloem present in the aerial axis of species of *Chironia*, *Crawfurdia*, *Orphium*, and in the root of various species of *Blackstonia*, *Canscora*, *Centaurium*, *Chironia*, *Cicendia*, *Crawfurdia*, *Eustoma*, *Exacum*, *Gentiana*, *Halenia*, *Ixanthus*, *Sabbatia*, *Swertia*.

B. MENYANTHOIDEAE

Summary

The Menyanthoideae constitute a widely distributed group of herbs which occur chiefly in marshes or in fresh water. They exhibit considerable anatomical differences from the Gentianoideae, and it is, therefore, very surprising to the anatomist that the 2 groups can have affinities with one another. The absence of **intraxylary phloem** and the occurrence of a more dissected type of **vascular system** composed of isolated or scattered bundles provide noteworthy differences. A well-developed system of **intercellular canals** and **spaces** is also characteristic, but this is doubtless correlated with the marshy or aquatic environment of the plants. Branched, sclerenchymatous idioblasts, similar to those of the Nymphaeaceae, are also noteworthy.

LEAF

Dorsiventral or isobilateral. Uniseriate, mucilaginous **hairs** present on the buds of species of *Limnanthemum* and *Menyanthes*. **Stomata** ranunculaceous; usually present on both surfaces, but confined to the upper side of the floating leaves of *Limnanthemum*. **Hydathodes** common at the leaf margins, situated at the enlarged terminations of the veins. Discoid groups of small, polygonal, tanniniferous cells of unknown physiological significance, occur on raised portions of the lower epidermis of species of *Villarsia*. These cells render the lower surface like shagreen when seen with the naked eye. Branched, thick-walled idioblasts with arms projecting into the intercellular spaces of the mesophyll (cf. those of the Nymphaeaceae) recorded in *Limnanthemum*, *Liparophyllum*, *Villarsia*, but absent from *Menyanthes*, *Nephrophyllidium*, and some species of *Villarsia*. **Petiole** of *Limnanthemum peltatum* Gmel. (Fig. 216 G) in transverse sections through the distal end, exhibiting an arc of widely spaced bundles, the median one being considerably larger than the remainder. Vascular bundles likewise widely spaced, but arranged in a definite circle in *Menyanthes trifoliata* Linn. (Fig. 216 H). Surrounding cortical tissue very lacunar in both species. The structure of the last 2 species was examined at Kew. An open arc of isolated vascular bundles in *Nephrophyllidium*, scattered bundles in species of *Limnanthemum* belonging to the section *Nymphaeanthe*, and 2 concentric arcs of bundles with adaxial xylem in *Villarsia lasiosperma* F. v. M. recorded by Solereder. **Crystals** of calcium oxalate absent.

AXIS (Fig. 216 B, E)

INFLORESCENCE AXIS AND RHIZOME

The following features were noted at Kew in the flower-bearing axis of *Limnanthemum peltatum* Gmel. (Fig. 216 E) and *Menyanthes trifoliata* Linn. **Cortex** of both species containing numerous, vertically elongated air cavities giving the tissue a lace-like appearance in transverse sections. Branched, sclerenchymatous idioblasts (Fig. 216 B), recalling those of the Nymphaeaceae, project into the intercellular cavities from the surrounding cells in *Limnanthemum* but not in *Menyanthes*. **Endodermis** conspicuous in *Limnanthemum*. **Vascular bundles** widely spaced and wholly unconnected by interfascicular cambium in *Limnanthemum* and *Menyanthes*. Vessels spirally thickened in *Limnanthemum*; those of *Menyanthes* thick-walled and provided with scalariform lateral pitting; perforations simple in *Limnanthemum* but scalariform plates may occur in *Menyanthes*. The actual perforations were not clearly visible in the material available, and a more complete investigation would be necessary to elucidate the structure of the tracheary elements. **Pith** very lacunar in *Menyanthes*. **Intraxylary phloem** absent.

The following information has been recorded by Solereder. **Vascular bundles** in the inflorescence axis of *Nephrophyllidium crista-galli* Gilg embedded in a ring of pericyclic sclerenchyma.

In the rhizome of *Menyanthes trifoliata* Solereder records the occurrence of scattered vascular bundles, supported both on the outside and inside by well-developed strands of fibres. Bundles also widely spaced and provided with a ring of fibres towards the exterior in the corresponding position in *Villarsia*. Rhizome of *Limnanthemum peltatum* containing an almost complete ring of xylem and phloem, but not accompanied by sclerenchyma. Scattered bundles also recorded by Solereder in the axis of species of *Limnanthemum* belonging to the section *Nymphaeanthe*. Centre of the axis in these species generally occupied by a large 'double bundle' consisting of 2 vascular strands with their xylem groups directed towards one another. The central bundle may represent the true stele, whilst the remainder are cortical. Inner portions of the vascular bundles throughout the tribe generally composed of large groups of unlignified parenchyma, thought by some botanists to be homologous with the intraxylary phloem of the Gentianoideae. Intercellular canals sometimes arise in this tissue in *Menyanthes trifoliata*. **Cortical vascular bundles** recorded in *Limnanthemum peltatum* and *Villarsia exultata* F. v. M., those of the last species inversely orientated and in contact with a ring of pericyclic sclerenchyma. **Secretory elements.** Cells containing tannin recorded in the rhizome of *Nephrophyllidium* and *Villarsia*.

ROOT

The following particulars have been recorded by Perrot (1691). Primary **cortex** consisting of rounded cells interspersed with irregular intercellular spaces; sclerenchymatous idioblasts generally absent. **Vascular system** composed of numerous, distinct bundles, with little or no secondary thickening. Surface of the root of *Nephrophyllidium crista-galli* Gilg said by Solereder to be covered with a cork-like tissue containing a mucilaginous substance.

TAXONOMIC NOTES

The anatomical differences between the Gentianoideae and Menyanthoideae are very obvious. This may be partly correlated with the marshy or aquatic habitats of the Menyanthoideae, but nevertheless the absence of intraxylary phloem and the dissected vascular system of the Menyanthoideae are features so unlike those of the Gentianoideae that the existence of close affinities between the 2 tribes seems unlikely. Lindsey (1375), after making an anatomical comparison of the floral structure of the 2 groups, concluded that the Menyanthoideae should be given the status of a distinct family.

ECONOMIC USES

The family includes several plants of medicinal interest, the most familiar of which is the dried rhizome and root of *Gentiana lutea* Linn., an infusion of which stimulates gastric secretion. The rootstock occurs in branched pieces up to 60 cm. long and 4–8 cm. thick at the crown. The rhizome of many other species of *Gentiana* is thinner. The rhizome is characterized by the transverse scars of the leaves formed in succeeding years, and, near the apical growing-point, by the yellowish bases of the leaves of the current season's growth. Roots yellowish-brown, only slightly branched, and longitudinally wrinkled. Microscopical features of the rootstock include the narrow layer of cork; the narrow cortex of fairly thick-walled parenchyma; the broad, mainly parenchymatous phloem with scattered strands of sieve tissue embedded in it; the xylem cylinder, with no medullary rays and including solitary and grouped vessels with scalariform and reticulate pits, and annular and spiral thickening; the strands of interxylary phloem; the yellowish drops of oil in the parenchymatous elements; the minute, acicular, and other kinds of crystals of calcium oxalate; the absence of stone cells and fibres. All of the tissues, except the cork and xylem, become blue when treated with chlor-zinc-iodide. The roots and rhizomes of other species of *Gentiana* are sometimes substituted. The morphology and anatomy of many of these, with special reference to interspecific differences, have been described by Osterwalder (1644).

Chirata, which also stimulates the digestion, is the dried plant of *Swertia chirata* Buch-Ham. obtained from north India. Various other species of *Swertia* are used as substitutes. The British species *Menyanthes trifoliata* Linn. has also been used as a bitter tonic. The family includes numerous ornamental plants, especially species of *Gentiana*.

GENERA DESCRIBED

A. GENTIANOIDEAE

Bartonia, Belmontia, Blackstonia,* Canscora, Centaurium, Chironia, Cicendia, Cotylanthera, Crawfurdia, Deianira, Enicostema, Eustoma, Exacum,* Geniostemon, Gentiana,* Halenia, Hockinia, Ixanthus, Lagenanthus, Lehmanniella, Leiphamos, Lisianthus, Microcala, Neurotheca, Obolaria, Orphium, Pleurogyna, Prepusa, Purdieanthus, Rusbyanthus, Sabbatia, Schultesia, Sebaea, Senaea, Swertia, Voyria, Voyriella, Zonanthus.

B. MENYANTHOIDEAE

Limnanthemum,* Liparophyllum, Menyanthes,* Nephrophyllidium, Villarsia.

* Represented in the Kew slide collection.

LITERATURE

On General Anatomy

Betts 189, Col 445, Hall 873, Lindsey 1375, Martens 1448, Osterwalder 1644, Perrot 1691, Sabnis 1977, Sayeedud-Din 2014.

193. POLEMONIACEAE

(FIG. 217 on p. 940)

SUMMARY

This family, which occurs in North America and on the Andes, is mainly herbaceous, but includes a few woody and climbing species. In the dorsiventral or isobilateral leaf, the **stomata** are usually ranunculaceous, although rubiaceous types are also known to occur. The **endodermis** in the stem is frequently well developed, and, in some species, provided with casparian thickenings. The **phloem** is usually in the form of a continuous ring devoid of mechanical elements, but, in certain species of *Gilia* and *Phlox*, it occurs as

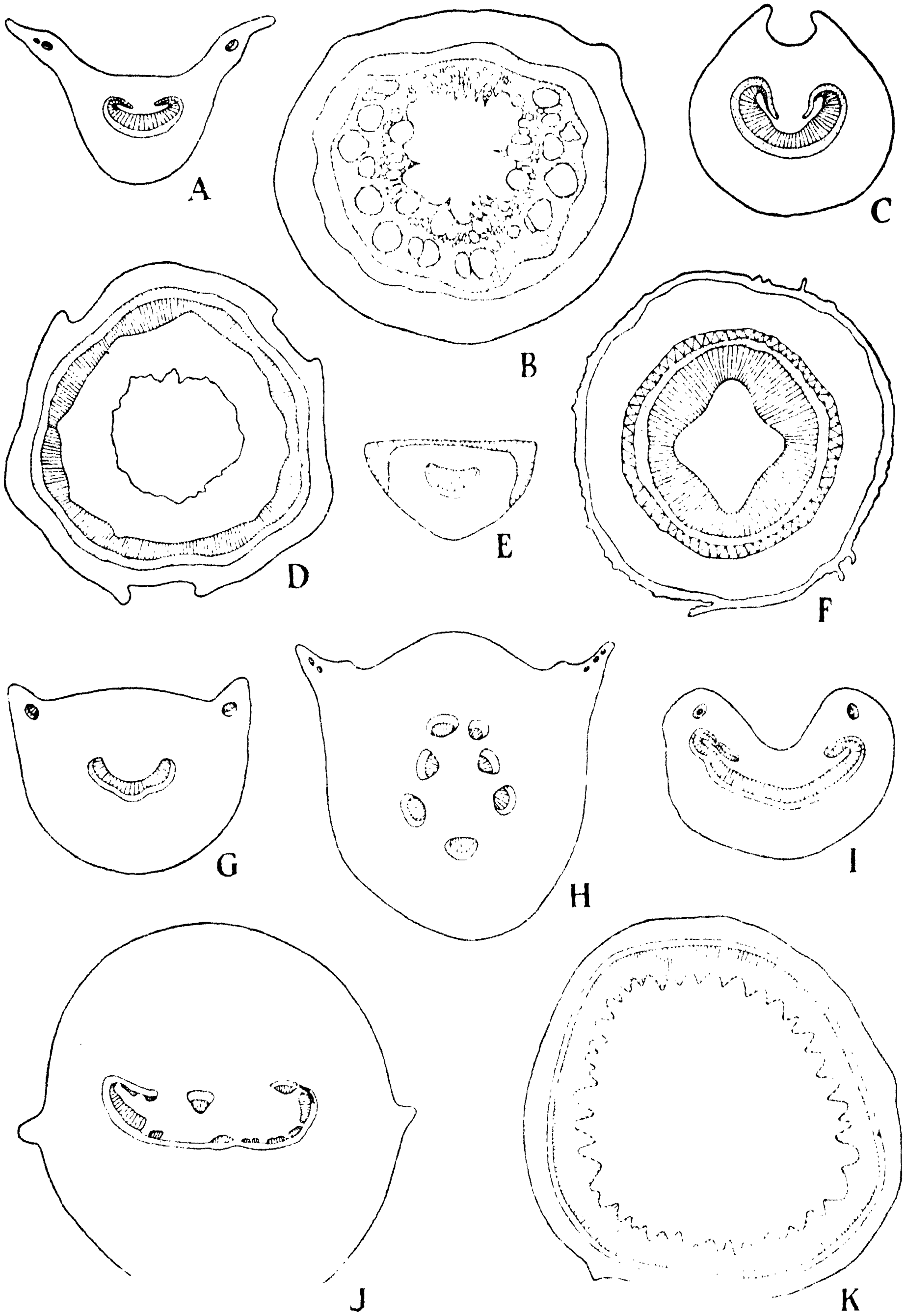


FIG. 217. *POLEMONIACEAE*, A–F; *HYDROPHYLLACEAE*, G–K

A, *Polemonium caeruleum* Linn. Petiole × 10. B, *Cobaea scandens* Cav. Stem × 21. C, *C. scandens* Cav. Petiole × 15. D, *Polemonium caeruleum* Linn. Stem × 9. E, *Gilia elegans* Linn. Petiole × 18. F, *Phlox subulata* Linn. Stem × 33 [outer cortex of small parenchymatous cells; inner cortex of much larger sclerosed cells]. G, *Hydrophyllum virginicum* Linn. Petiole × 13. H, *H. virginicum* Linn. Peduncle × 9. I, *Phacelia tanacetifolia* Benth. Petiole × 9. J, *Hydrophyllum canadense* Linn. Rhizome × 5 K, *Phacelia tanacetifolia* Benth. Stem × 7.

strands of sieve tubes embedded in sclerenchymatous ground-tissue. The **xylem,** in the rather limited material which has been examined, is in the form of a continuous cylinder, often without well-defined medullary rays; vessels usually small (but large in *Cobaea scandens* Cav.) and frequently arranged in radial rows.

LEAF

Dorsiventral or isobilateral. **Hairs** mostly of the following uniseriate kinds, very rarely with lateral protrusions: (i) short conical hairs placed obliquely to the leaf; (ii) longer, curved or straight, stiff hairs; (iii) worm-like (arachnoid) woolly hairs. Walls of the uniseriate hairs varying in thickness, occasionally slightly silicified. Glandular hairs, each with a uniseriate stalk of variable length and a unicellular or multicellular head, occur in species of *Bonplandia, Cantua, Collomia, Gilia, Loeselia, Phlox, Polemonium.* The more detailed structure of the glandular hairs is valuable in the identification of species. Glandular leaf teeth, situated at the ends of bundles and consisting of mucilaginous parenchyma accompanied by stomata on the upper surface, recorded in young leaves of *Polemonium caeruleum* Linn. **Cuticle** smooth, finely striated, granular or verrucose. **Epidermis,** in species with narrow leaves, consisting of cells elongated in the direction of the median vein and occasionally appearing to be almost prosenchymatous in surface view. Anticlinal walls of the epidermal cells of species with broader leaves either sinuous or, more rarely, straight. Outer walls tending to be mucilaginous in many species of *Collomia, Gilia, Phlox.* Isolated epidermal cells at the margin and towards the apex of the leaf of species of *Bonplandia, Collomia, Gilia, Loeselia* and *Phlox* exhibit papillae, sometimes accompanied by silicified bodies resembling cystoliths. **Hypoderm,** composed of cells with thickened cellulose walls, confined to the leaf margin and the region above the median veins. **Stomata** generally ranunculaceous, but tending to be rubiaceous in species with narrow leaves; usually present on both surfaces, especially in species with narrow leaves; rarely confined to the lower side. Stomata in the narrow, imbricate, adpressed leaves of *Phlox hoodii* Richards present on both surfaces, but only on the hair-protected basal part of the leaf. **Mesophyll** usually devoid of large intercellular spaces even in the spongy tissue; central part, especially around the vascular bundles, consisting of large, aqueous cells. Parenchymatous sheaths of the **veins** sometimes suberized. Vascular bundles commonly accompanied by sclerenchyma on either side. A similar tissue in the xylem itself sometimes makes the structure appear to be anomalous. **Petiole** of *Cobaea scandens* Cav. (Fig. 217 C) exhibiting, in transverse sections through the distal end, a solitary, shallow, crescentic vascular strand with strongly incurved ends, the latter consisting chiefly of phloem. Main vascular strand somewhat similar in *Polemonium caeruleum* Linn. (Fig. 217 A), but incurved ends consisting of xylem as well as phloem; median bundle slightly crescentic in *Gilia elegans* Linn. (Fig. 217 E) and species of *Phlox* examined at Kew. Accessory bundles in the wings observed in *Phlox* and *Polemonium.*

AXIS

STEM (Fig. 217 B, D, F)

Cork not very fully investigated; said to arise in the outer part of the cortex or in the pericyclic region in different species of *Phlox* (Fig. 217 F). Primary

cortex often partly collenchymatous and sometimes including mucilaginous and/or sclerotic cells, e.g. stone cells in *P. paniculata* Linn. **Endodermis** well defined in some of the species examined at Kew; consisting of large, tangentially elongated cells in *Collomia linearis* Nutt.; developing rather early and consisting of uniformly thickened cells in *Gilia densiflora* Benth.; endodermal cells provided with well-defined casparian thickenings in *Phlox paniculata* and *Polemonium caeruleum* Linn. **Pericycle** containing a continuous ring or isolated strands of rather inconspicuous fibres in different species. Pericyclic fibres not indicated in Fig. 217 B and D. **Phloem** consisting of small cells unsupported by mechanical elements; generally in the form of a continuous ring, or, in species of *Gilia* and *Phlox*, in the form of small strands embedded in lignified tissue, the latter being in contact with the xylem on the inside.

Xylem, in all of the species examined at Kew, in the form of a continuous cylinder, without any well-defined medullary rays. Vessels in the same species usually not much wider than the cells of the surrounding parenchymatous ground tissue; generally tending to be in radial rows, especially those towards the pith. Vessels in radial rows and about 40 μ in diameter also recorded by Solereder in the xylem of the more woody species. Vessels of *Cobaea scandens* Cav. (Fig. 217 B) up to about 200 μ in radial diameter, and probably larger in the more mature stems. Vessel perforations mostly simple in species of *Cobaea*, *Collomia*, *Loeselia*, *Phlox*; infrequent, scalariform perforation plates with 1–10 bars recorded by Solereder amongst the simple ones in species of *Gilia*, *Loeselia*, *Polemonium*. Wood fibres with simple or inconspicuously bordered pits in *Collomia stemosiphon* Kunze and *Loeselia mexicana* Brandt. Rays in the same species uniseriate. **Pith** occasionally including sclerotic cells similar to those in the cortex. **Secretory elements.** Intercellular spaces filled with a yellow secretion recorded by Solereder in the phloem of *Cobaea scandens*. **Crystals** not seen. The **developmental anatomy** of *Phlox drummondii* Hook. has been investigated by Miller and Wetmore (1535, 1536).

ROOT

The following particulars concerning the root of *Phlox ovata* Linn. have been recorded by Kraemer (1273). **Root hairs** present. **Hypodermis** consisting of radially elongated, pentagonal cells. **Cortex** composed of 12–20 rows of ellipsoidal, rather thin-walled, parenchymatous cells, some of the latter containing small starch grains. Primary **vascular structure** triarch to pentarch.

TAXONOMIC NOTES

The stem structure is not unlike that of the Gentianoideae, apart from the absence of intraxylary phloem.

ECONOMIC USES

Various members of the family are cultivated for ornamental purposes.

GENERA DESCRIBED

Bonplandia, Cantua, Cobaea,* Collomia,* Gilia,* Loeselia, Phlox,* Polemonium.*

* Represented in the Kew slide collection.

LITERATURE

On General Anatomy

Brand 254, Kraemer 1273, Miller and Wetmore 1535, 1536.

194. HYDROPHYLLACEAE

(FIG. 217 on p. 940)

SUMMARY

(i) GENERAL

A mainly North American herbaceous family, but some species tend to be shrubby. The more noteworthy anatomical features include the presence of covering and glandular **hairs,** the ranunculaceous **stomata** of the leaves, the frequently well-defined **endodermis,** and the lack of well-developed sclerenchyma in the stem; the infrequence of **crystals.**

(ii) WOOD

Vessels small to medium-sized, sometimes exclusively solitary, tending to be ring-porous, intervascular pitting alternate and small, members of medium length. **Parenchyma** apotracheal, diffuse. **Rays** typically up to 3–4 cells wide, heterogeneous to homogeneous. **Fibres** with bordered pits, moderately short.

LEAF

Commonly dorsiventral, but sometimes tending to be isobilateral. Conical, unicellular, thick-walled **hairs** widely distributed; occasionally becoming bicellular; sometimes seated on multicellular pedicels, e.g. in species of *Phacelia* and *Wigandia*; frequently encrusted with calcium carbonate or containing bodies resembling cystoliths in species of *Codon*, *Emmenanthe*, *Hydrophyllum*, *Nemophila*, *Phacelia*. Unicellular, arachnoid hairs form a dense felt on the lower surface of the leaf in *Eriodictyon californicum* Greene (syn. *E. glutinosum* Benth.). Uniseriate, multicellular hairs recorded in *Ellisiophyllum*, *Romanzoffia*, *Tricardia*, and stellate types in *Hydrophyllum*. Spines also occur in some genera. Stalked glandular hairs recorded in species of *Codon*, *Ellisia*, *Hydrolea*, *Hydrophyllum*, *Nama*, *Phacelia*, *Romanzoffia*, *Wigandia*. Differences in the nature and number of cells in the stalk and head of these glands are valuable in the identification of species. Peltate glands recorded in *Eriodictyon*. **Epidermis** often consisting of cells with very sinuous anticlinal walls.

Stomata present on both surfaces or confined to the lower side; ranunculaceous. **Mesophyll** including transversely septate palisade cells in *Eriodictyon californicum*. **Petiole** provided with an arc-shaped vascular strand, sometimes with incurved ends, in species of *Hydrophyllum* (Fig. 217 G) and *Phacelia* (Fig. 217 I); median strand somewhat similar but without incurved ends in other species of *Phacelia*; median strand small and slightly crescentic in *Nemophila*. A cylindrical vascular strand enclosing a medullary bundle, and accompanied on the adaxial side by a few smaller, subsidiary strands, recorded by Solereder in *Wigandia carcasana* H. B. et K. Smaller accessory bundles in the wings noted in all of the species examined. **Crystals** not very fully investigated, but clusters recorded in species of *Eriodictyon*, *Hydrolea*, *Phacelia*.

AXIS

STEM (INCLUDING PEDUNCLE AND RHIZOME) (Fig. 217 H, J, K)

Cork arising superficially in the few investigated species of *Eriodictyon, Nama, Wigandia.* Primary **cortex** frequently composed of thin-walled cells in herbaceous species; traversed by air-canals surrounded by cells filled with cluster crystals in *Hydrolea.* **Endodermis** frequently well defined. A few thin-walled fibres noted in the **pericycle** in species of *Hydrophyllum* and *Nemophila,* but none seen in *Phacelia.* **Phloem** in the form of large strands in species of *Nama* and *Phacelia*; occurring as very small strands in *Hydrolea* and *Romanzoffia,* as a strongly developed ring in *Hydrophyllum, Nama, Tricardia, Wigandia,* or a weak ring in species of *Nama* and *Nemophila.* **Xylem** seen to be in the form of a continuous cylinder traversed by narrow rays in 2 species of *Phacelia* (Fig. 217 K), and slightly or fully dissected into separate bundles by broader rays in the peduncle of species of *Hydrophyllum* (Fig. 217 H) and *Nemophila* examined at Kew. The structure of the rhizome of *Hydrophyllum canadense* Linn. is shown in Fig. 217 J. Vascular bundles in herbaceous species are described by Solereder as simple and variously arranged; as separated from one another by strips of ground tissue in *Ellisia* and *Hydrophyllum,* as more or less united in *Nemophila,* and as forming a closed ring in *Emmenanthe, Nama, Phacelia.* Vessels arranged in definite radial rows in *Phacelia*; perforations simple in the species examined at Kew. **Pith** lignified in *Eriodictyon californicum* Greene. Cluster **crystals** noted at Kew in the cortex of 1 species of *Phacelia,* and in the pith of 1 species of *Hydrophyllum*; none seen in *Nemophila* or in the species of *Phacelia* examined.

WOOD

Vessels mostly about 65 μ in diameter (1886), extremely small (mean tangential diameter less than 25 μ) in some species of *Eriodictyon* and about 115 μ in *Wigandia*; almost exclusively solitary in *Eriodictyon* and *Nama* (1154), often with a marked tendency to arrangement in tangential rows; from about 30 per sq. mm. in *Wigandia* to over 200 in *Eriodictyon trichocalyx* A. A. Heller; tending to be ring-porous in *Eriodictyon* and distinctly so in some rings. Perforations simple. Intervascular pitting alternate, small; pits to ray and wood parenchyma similar. Mean member length in *Eriodictyon* 0·25–0·5 mm. (76). **Parenchyma** apotracheal, scattered among the fibres, and, according to Record and Hess (1886), sometimes reticulate. Strands usually of 2 cells in *Eriodictyon,* with some fusiform cells. **Rays** up to 3 cells wide in *Eriodictyon* and *Nama,* rather wider and occasionally up to 6 cells in *Wigandia* (1886); less than 1 mm. high; uniseriates in *Eriodictyon* moderately numerous, but low and mostly only 1–3 cells high; composed of both procumbent and upright cells; 7–13 rays per mm.; heterogeneous, with a few marginal rows of square or upright cells in *Eriodictyon* and *Nama,* almost homogeneous in *Wigandia.* **Fibres** with numerous bordered pits on all walls. Walls thin. Mean length in *Eriodictyon* 0·7–0·8 mm.

ECONOMIC USES

The dried leaves of *Eriodictyon californicum* Greene (syn. *E. glutinosum* Benth.) from California are used in the preparation of a bitter tonic and for various other medicinal purposes. The oblong, lanceolate leaves, 5–15 cm.

long and 1–3 cm. broad, with an acute apex and more or less incurved, irregularly serrate margins, are characterized microscopically by the following features cited by Tunman (2290), Cooper (463), and Honer and Miller (1082). Lower surface covered with a woolly tomentum of unicellular, thick-walled hairs with somewhat swollen bases; glandular trichomes with short, 2-celled stalks bearing heads composed of up to 8 or more cells. Honer and Miller (1082) have demonstrated that the heads of the glands are often composed of more than the 8 cells observed by previous authors. Cells of the upper epidermis with slightly sinuous, anticlinal walls. Sporadic stomata on the upper surface, those on the lower side difficult to observe on account of the hairs, but mostly confined to the invaginated portions of the surface. Mesophyll including 3–7 layers of palisade cells. Midrib containing 1 relatively large, abaxial, and 2 smaller, adaxial, vascular bundles, the vessels in the xylem being arranged in radial rows and separated by uniseriate rays. Petiole similar in structure to that of the midrib, but with the 2 small bundles closer to and sometimes fused with the abaxial strand. Idioblasts containing large cluster crystals present in the palisade tissue and in the region of the endodermal sheaths around the vascular bundles.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Codon, Ellisia, Ellisiophyllum, Emmenanthe, Eriodictyon, Hydrolea, Hydrophyllum,* Nama, Nemophila,* Phacelia,* Romanzoffia, Tricardia, Wigandia.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Eriodictyon, (Nama), Wigandia.

LITERATURE

(i) *On General Anatomy*

Brand **255**, Cooper **463**, Honer and Miller **1082**, Tunman **2290**.

(ii) *On Wood Structure*

Bailey **76**, Janssonius **1154**, Record **1843**, **1851**, **1864–6**, Record and Hess **1886**.

195. BORAGINACEAE

(FIG. 218 on p. 946; FIG. 219 on p. 949; FIG. 220 on p. 950; FIG. 221 on p. 952)

SUMMARY

(i) GENERAL

The familiar European members of this family are herbs, but shrubby and arboreal genera such as *Cordia*, *Ehretia*, and *Tournefortia* occur, chiefly in tropical countries. One of the most striking features of the herbaceous forms is the covering of thick-walled, harsh, unicellular **hairs** which have a characteristic rough feeling when handled. Bodies resembling **cystoliths** are frequent in the basal parts of these hairs and sometimes in the adjacent epidermal cells. Similar hairs also occur, although less frequently, in the arboreal genera. Bider (196) cites the work of Jakoiljevic who has shown that

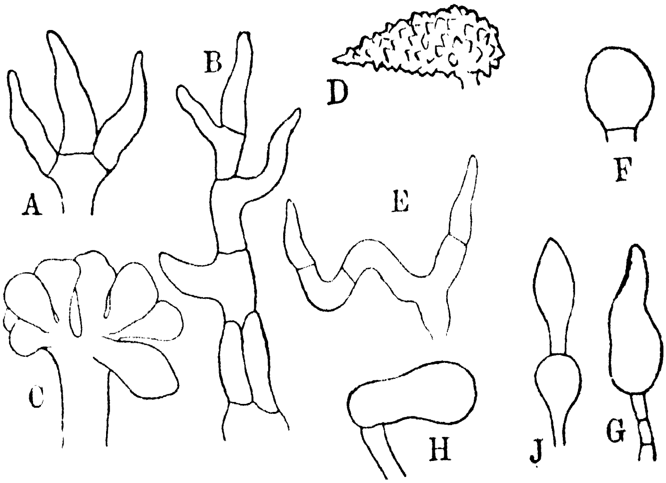


FIG. 218. *BORAGINACEAE*

Clothing and glandular hairs. A–B, *Eremocordia*. C, *Cordiae myxae* sp. aff. D, ***Cordia superba*** Cham. E, ***C. subopposita*** A. DC. F, *Varronia*. G, *Cordia affinis* Fres. H, *C. superba* Cham. J, ***C. glandulosa*** Fres.—After Mez.

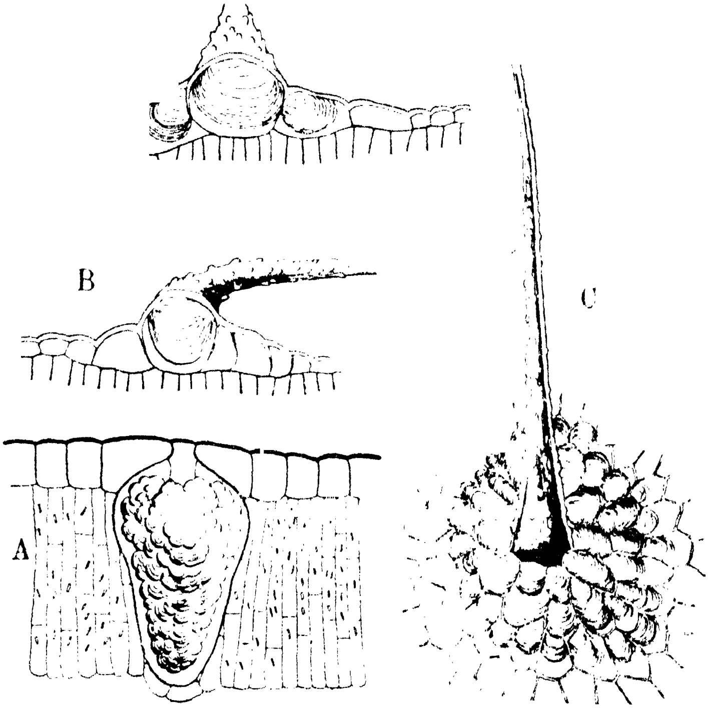


FIG. 219. *BORAGINACEAE*

A, Portion of a transverse section of a leaf of *Cordia gerascanthus* Linn., with a cystolith-cell. B–D, Cystolith-like structures in the hairs and adjacent subsidiary cells in *Lithospermum officinale* L.—By Solereder.

the structure of these hairs and the mode of deposition of the calcareous infiltration are constant for any given species. Species which possess them do not flourish unless lime is present in the soil. On the other hand, the number and size of the cystolith-like bodies varies at different times of the year and also according to the amount of calcareous material in the soil. Bider also found the nature of the cuticular striations at the bases of the hairs and elsewhere on the leaf epidermis to be unreliable for diagnostic purposes. Other kinds of hairs, including stalked glands with unicellular heads, are also to be found, but are less widely distributed. The structure of the mesophyll of the leaf often exhibits a wide range of variations within a single genus. The **stomata** are usually ranunculaceous. The **petiole** of herbaceous species, in transverse sections through the distal end, generally shows an arc of separate vascular bundles, whilst in species of *Cordia*, *Ehretia*, and *Patagonula* there is a cylindrical strand with subsidiary bundles on the adaxial side and/or in the 'pith'. The **xylem,** in the young stem of arboreal species and in the main axis of herbs, usually has the form of a closed ring as seen in transverse sections. Cluster and other kinds of **crystals** are widely distributed. **Ant domatia** occur in the *Gerascanthus* and *Physocladia* sections of *Cordia.* The morphology and biological functions of those of *Cordia nodosa* Lam. have been investigated by Bailey (72), and those of the section *Gerascanthus* by Chodat and Carisso (405). **Anomalous structure.** Furrowed xylem recorded in 1 species.

(ii) WOOD

Vessels very small to large, often in clusters and sometimes with a diagonal or ulmiform pattern, often tending to be ring-porous, perforations simple, intervascular pitting alternate, pits to parenchyma usually similar, sometimes larger in *Cordia*, members of medium length to extremely short. **Parenchyma** varying from uniseriate to broad bands, or from a few cells about the vessels to aliform and confluent. **Rays** mostly 4–6 cells wide, with very few uniseriates, heterogeneous with 1–3 marginal rows to homogeneous. **Fibres** with simple or bordered pits, often septate, moderately short to moderately long. **Vasicentric tracheids** sometimes present.

LEAF

Very variable, ranging from isobilateral to dorsiventral within a genus. Isobilateral structure recorded in species of *Arnebia*, *Cordia*, *Ehretia*, *Heliotropium*, *Lithospermum*, *Sericostoma*, *Tournefortia*, *Trichodesma* (Chodat and Vischer 403, Evenari 665, Kienholz 1236, Sabnis 1977, Starr 2188, Sayeedud-Din 2013). Arm palisade cells sometimes present on the lower side in *Arnebia*, *Heliotropium*, *Trichodesma* (Sabnis 1977). **Hairs** including glandular and non-glandular types (Figs. 218 and 219). (i) The rough surface of members of the Boragineae is generally caused by unicellular, but occasionally 2- or more-celled, conical, calcified and/or silicified bristles sometimes described as boraginaceous hairs. Bodies resembling cystoliths (Fig. 219 B–D) present in the usually swollen, basal portions of these hairs and sometimes in the adjacent epidermal and mesophyll cells. Variations in the length, curvature, and degree of calcification of the hairs occur in different genera and species, one of the most extreme types being represented by trichomes consisting of small bulbous bases, bearing long, hypha-like terminal portions, e.g. in species of *Borago*, *Cynoglossum*, *Eritrichium*, *Heliotropium*, *Lithospermum*, *Myosotis*, *Symphytum*. (ii) Unicellular, unbranched hairs, e.g. in *Tournefortia*. (iii) Simple uniseriate trichomes in species of *Borago*, *Cordia*, *Echium*, *Myosotis*, *Symphytum*. (iv) Branched, multicellular trichomes in species of *Cordia* (Fig. 218 A–E). (v) Unicellular and multicellular hairs with 2 equal or unequal arms and sometimes with knobbed heads in species of *Cordia* and *Halgania*. (vi) Stellate hairs recorded in *Cordia*. (vii) Retort-shaped hairs, especially on the lower surface, present in *Heliotropium rotundifolium* Sieb. (Evenari 665). (viii) Glandular hairs (Fig. 218 F–J) with short or long stalks and variously shaped, unicellular heads recorded in species of *Alkanna*, *Anchusa*, *Borago*, *Cordia*, *Echium*, *Heliotropium*, *Lithospermum*, *Lycopsis*, *Nonnea*, *Onosma*, *Patagonula*, *Pulmonaria*, *Symphytum*. Besides the bodies resembling cystoliths in the bases of the hairs and adjacent epidermal cells, independent cystoliths (Fig. 219 A) occur in *Cordia* and *Tournefortia* and probably other genera as well, their distribution being valuable for the identification of species, particularly in *Cordia*. **Epidermis** consisting of cells with straight or sinuous anticlinal walls; papillose on the lower surface in some species of *Cordia*. **Hypoderm** not recorded in any member of the family. **Stomata** usually ranunculaceous, but typical subsidiary cells recorded by Bider (196) in *Cynoglossum officinale* Linn. and in *Cerinthe*; considerably elevated above the leaf surface in some species of *Cordia*; commonly occurring on both surfaces, but, in *Cordia*, usually confined to the lower side. **Mesophyll** including sclerenchymatous fibres in *Cordia sprucii* Mez.

Vascular bundles of the **veins** vertically transcurrent by sclerenchyma in the species of *Arnebia*, *Ehretia*, *Heliotropium* (pro parte), and *Trichodesma* investigated by Sabnis (1977). Vascular bundles of the smaller veins also vertically transcurrent by sclerenchyma, at least on the upper side, in *Cordia* according to Solereder. Vascular bundles not accompanied by sclerenchyma in *Tournefortia* according to Kienholz (1236). Bicollateral bundles recorded by Sabnis (1977) in *Heliotropium paniculatum* R. Br. **Petiole** (Fig. 220 A–H and J), in transverse sections through the distal end, provided, in most herbaceous species, with an arc of up to about 12 separate vascular bundles with the median one larger than the remainder; containing a simple arc of xylem and phloem in *Cordia* (pro parte) and species of *Patagonula*; main vascular strand in *Cordia gerascanthus* Linn. (Fig. 220 E) and *Ehretia thyrsiflora* Nakai, in the form of an almost or completely closed but adaxially flattened or concave ring of xylem and phloem, surrounding one or a number of small medullary strands and accompanied by other subsidiary bundles in the wings. **Crystals** include small solitary, acicular, clustered types, and, especially in the Cordioideae, crystal-sand. **Secretory elements.** Tanniniferous sacs recorded by Sabnis (1977) in the mesophyll and around the vascular bundles in species of *Ehretia* and *Heliotropium*.

According to Bider (196) the leaves in the different tribes of the Boraginaceae can be distinguished by the following characters.

CYNOGLOSSEAE. Leaf dorsiventral (incipient isobilateral structure in *Omphalodes*); absence of nodular bristles (Hugelborsten); absence of capitate hairs; occurrence of septate palisade cells and of resiniferous or tanniniferous canals beside the vascular bundles.

ERITRICHEAE. Leaf dorsiventral in *Asperugo* and *Eritrichium*, tending to be isobilateral in *Lappula*; absence of nodular bristles (Hugelborsten) (except in *Asperugo*); absence of capitate hairs; occurrence of resiniferous or tanniniferous canals beside the vascular bundles in *Lappula*.

ANCHUSEAE. Leaf dorsiventral (isobilateral only in *Alkanna*); nodular bristles (Hugelborsten) and capitate hairs always present.

LITHOSPERMEAE. Leaf dorsiventral in *Lithospermum* and *Myosotis*, isobilateral in *Cerinthe* and *Onosma*; nodular bristles (Hugelborsten) absent or imperfectly developed in the first 2, but always present in the last 2, genera; capitate hairs present only in *Onosma*.

ECHIEAE. Leaf dorsiventral. Nodular bristles (Hugelborsten) and capitate hairs present.

AXIS

STEM (Fig. 220 I, K, L)

Cork arising superficially in species of *Cordia*, *Ehretia*, *Moltkia*, and *Onosma*, in the middle of the cortex in *Heliotropium* and *Lithospermum*, in the pericycle in *Echium*. Cork cells thin-walled in species of *Tournefortia*, but some of them strongly thickened in species of *Cordia* and *Patagonula*. Primary **cortex,** especially in some of the herbaceous species, composed of rather large parenchymatous cells with very thin walls. An **endodermis** consisting of a layer of cells with granular contents noted by Sabnis (1977) in *Heliotropium paniculatum* Linn., but not in other members of the Boraginaceae examined by him. **Pericycle** very frequently devoid of sclerenchyma, e.g. in species of *Anchusa*, *Borago*, *Caccinia*, *Cerinthe*, *Cynoglossum*, *Echium*, *Lindelofia*, *Lithospermum*, *Macrotomia*, *Mertensia*, *Moltkia*, *Myosotis*, *Omphalodes*, *Onosma*, *Paracaryum*, and *Symphytum* amongst the genera examined at Kew; and in *Trichodesma indica* Br. according to Sabnis (1977). Isolated strands of pericyclic fibres noted or recorded in species of *Cordia*, *Ehretia*, *Heliotropium*, and *Pulmonaria*; a continuous composite ring of sclerenchyma recorded by Solereder in *Tournefortia hirsutissima* Linn.; and a composite ring of stone cells in *Sericostoma pauciflorum* Stocks by Sabnis (1977). Secondary **phloem** stratified into hard and soft portions in *Cordia* (Fig. 220 I) and *Ehretia*. **Xylem** constituting a continuous cylinder traversed by narrow rays in herbaceous species; for further details see Jodin (1182). Medullary rays broader and expanded at the distal ends in woody species, e.g. in *Cordia*. Vessels generally with simple perforations but reticulate plates recorded by Thompson (2254) in *Cordia* (see also under 'Wood'). **Pith** usually unlignified and often composed of large parenchymatous cells with very thin walls, especially in herbaceous species, but a pith consisting of small lignified cells was noted by Sabnis (1977) in a few species of *Arnebia*, *Ehretia*, *Heliotropium*. **Secretory cells** with unidentified contents observed at Kew in the cortex and pith of species of *Anchusa*, *Lindelofia*, *Macrotomia*, *Myosotis*, *Paracaryum*, *Pulmonaria*, *Symphytum*; in the phloem as well in species of *Caccinia*, *Cerinthe*, *Cordia*, *Cynoglossum*; in the pith only in species of *Mertensia* and *Onosma*. Solitary **crystals** noted only in the cortex of *Cordia* in the material examined at Kew; cluster crystals seen in the cortex of *Cordia* and in the cortex and phloem of *Ehretia*; abundant crystal-sand observed in the cortex, phloem, and pith of *Cordia*. Crystals apparently absent from species of

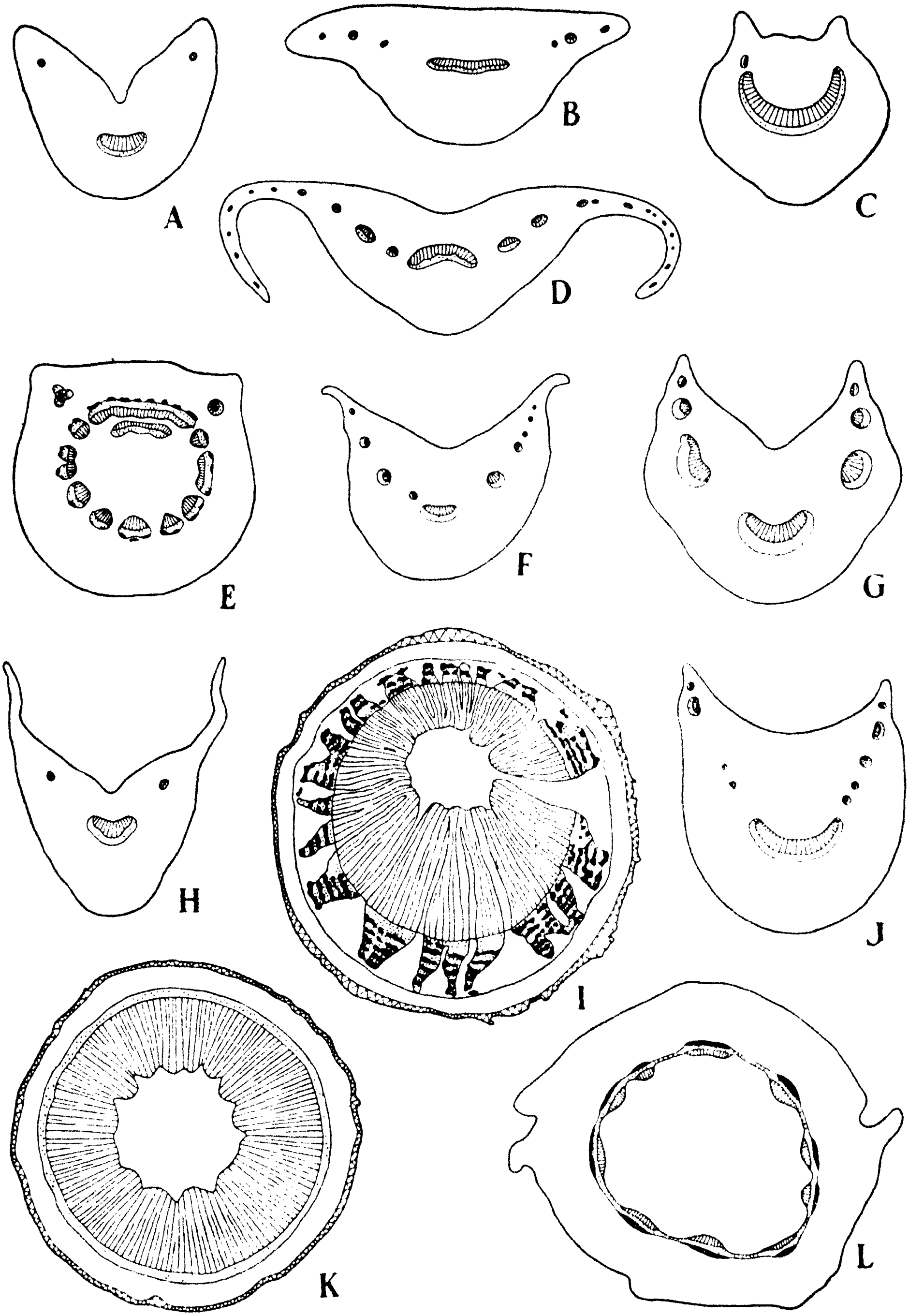


FIG. 220. *BORAGINACEAE*

A, *Mertensia echioides* Benth. Petiole × 27. B, *Caccinia strigosa* Boiss. Petiole × 7. C, *Heliotropium europaeum* Linn. Petiole × 19. D, *Echium pininana* Webb et Benth. Petiole × 6. E, *Cordia gerascanthus* Linn. Petiole × 18. F, *Symphytum officinale* Linn. Petiole × 9. G, *Paracaryum meliocarpum* Kern. Petiole × 12. H, *Pulmonaria rubra* Schott. Petiole × 7. I, *Cordia gerascanthus* Linn. Stem × 19. J, *Cynoglossum nervosum* Benth. Petiole × 8. K, *Echium* sp. Stem × 5. L, *Pulmonaria rubra* Schott. Stem × 8.

Anchusa, Borago, Caccinia, Cerinthe, Cynoglossum, Echium, Heliotropium, Lindelofia, Lithospermum, Macrotomia, Mertensia, Moltkia, Myosotis, Omphalodes, Onosma, Paracaryum, Pulmonaria, Symphytum.

WOOD (Fig. 221 C–J)

Vessels varying in size from very small (less than 50 μ mean tangential diameter), e.g. in *Bourreria* and *Rochefortia*, to large (more than 200 μ) in species of *Cordia*; exclusively solitary in *Rochefortia* and nearly all solitary in *Bourreria*, *Pteleocarpa*, and some species of *Cordia*; commonly in irregular clusters except in the above genera; in ulmiform tangential rows in *Patagonula* and *Saccellium* (Fig. 221 D) and sometimes in *Ehretia acuminata* R. Br.; according to Kanehira (1206) in flame-like (dendritic) groups in *E. longiflora* Champ. and *E. glaucescens* Hay.; typically rather few, but more than 40 per sq. mm. in *Bourreria* and *Rochefortia*, and fewer than 5 per sq. mm. in several species of *Cordia*. Ring-porous or semi-ring-porous in some species of *Auzemma*, *Bourreria*, *Cordia*, *Echium*, *Ehretia*, *Patagonula*, and *Saccellium*. Spiral thickening present in the narrow vessels of *Ehretia*, e.g. *E. acuminata* R. Br. and, according to Solereder, *Lithospermum*. Perforations simple, with rather wide rims and often nearly horizontal; a few reticulate plates occur in some species of *Cordia*, e.g. *C. myxa* L. (352, 2254), and Solereder refers to perforated pits in the narrow vessels of *Lithospermum*. Intervascular pitting alternate, small to minute in *Bourreria*, *Ehretia*, *Patagonula*, *Rochefortia*, and *Saccellium*, medium-sized in the other genera, and often with coalescent apertures, particularly in *Cordia*; pits to ray and wood parenchyma usually similar to the intervascular pitting but with some elongated pits in *Cordia*, *Echium*, and *Tournefortia* (1886). Tyloses often abundant in *Auxemma* and *Cordia*. Mean member length 0·15–0·5 mm. **Parenchyma** very variable in type; predominantly apotracheal, as scattered cells or numerous uniseriate lines, in *Bourreria*, *Ehretia* (Fig. 221 F), and *Rochefortia* and in more continuous bands in *Tournefortia*; diffuse, aliform and confluent in *Auxemma*, *Cordia* p.p., *Patagonula*, *Pteleocarpa*, and *Saccellium*, and in broad regular bands in some species of *Cordia* (Fig. 221 J); limited to a few cells round the vessels in *Echium*; the scattered cells in *Patagonula americana* L. often filled with crystal-sand, and single crystals sometimes present in *Cordia*. Strands usually of 2 cells, with moderately numerous fusiform cells in some species of *Cordia*, e.g. *C. holstii* Gurke and *C. macrostachya* R. et S. Storied in some species of *Cordia*, e.g. *C. dichotoma* Forst., *C. gharaf* (Forsk.) Ehrenb., *C. myxa*, and *C. suaveolens* Bl., and in *Tournefortia*. **Rays** mostly up to 4–6 cells wide, not more than 2–3 cells wide in *Bourreria*, *Rochefortia*, *Saccellium*, and *Tournefortia*, and up to 10 cells in some species of *Cordia*; often about 1 mm. high or slightly more, but occasionally low, e.g. in *Tournefortia*; uniseriate rays typically very few or lacking, composed of both procumbent and upright cells; 3–10 rays per mm., not more than 4 per mm. in some species of *Cordia* and *Ehretia*; heterogeneous (Kribs's Type II B), with 1–3 marginal rows of square or upright cells, in most of the genera, homogeneous (Kribs's Type II) in some species of *Cordia*, *Ehretia*, *Patagonula*, *Rochefortia*, and *Tournefortia*; sheath cells common in *Auzemma*, *Cordia*, and *Echium*. With crystals in the ordinary cells in a few species and sometimes with several crystals per cell or crystal-sand in *Cordia*. Locally in echelon or storied in *Tournefortia*. **Fibres**

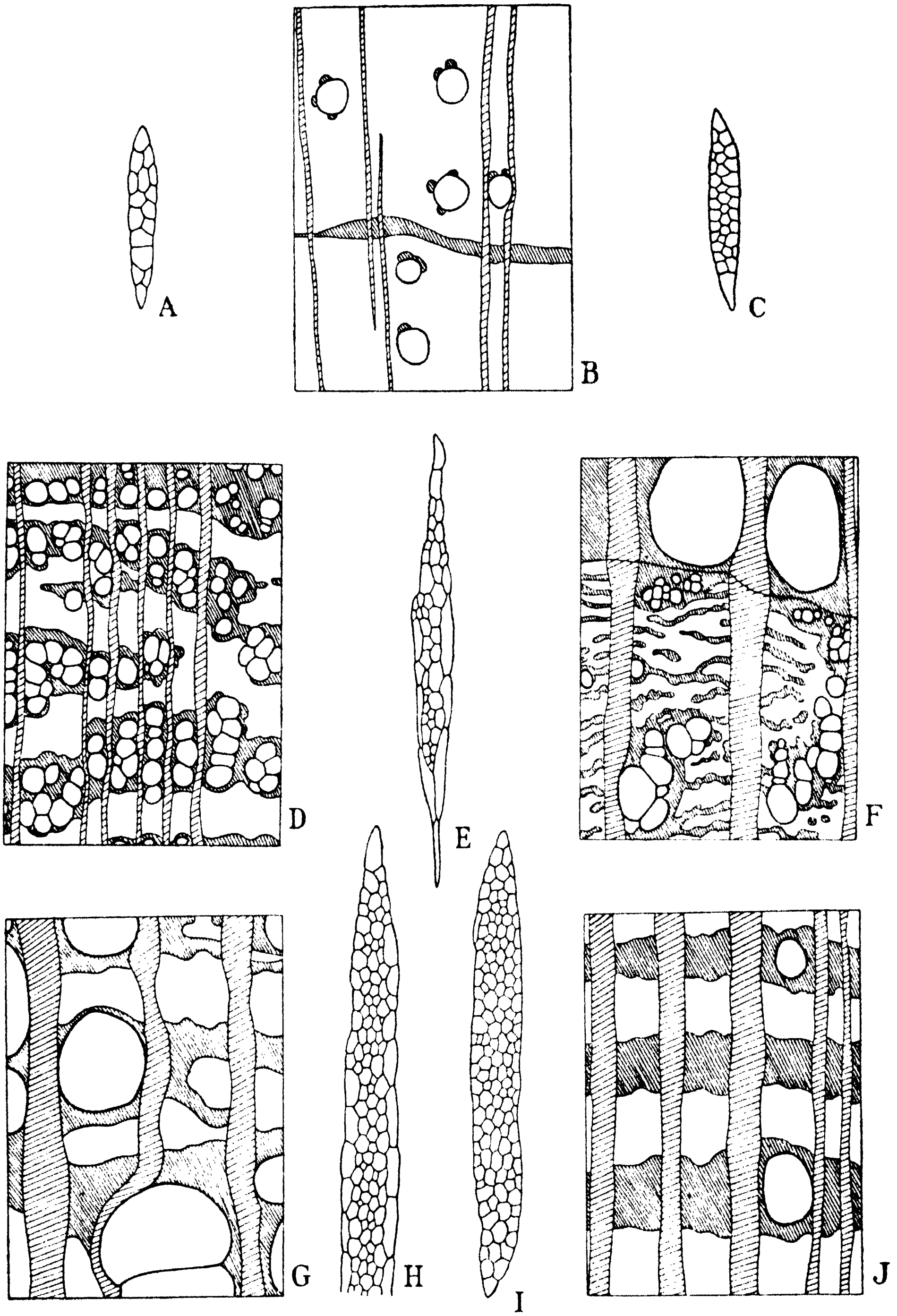


FIG. 221. *CONVOLVULACEAE*, A–B; *BORAGINACEAE*, C–J

A, *Convolvulus floridus* Linn. B, *C. floridus* Linn. C, *Saccellium lanceolatum* Humb. et Bonpl. D, *S. lanceolatum* Humb. et Bonpl. E, *Echium* sp. F, *Ehretia acuminata* R. Br. G, *Cordia fragrantissima* Kurz. H, *C. alliodora* Cham. I, *Ehretia acuminata* R. Br. J, *Cordia obliqua* Willd.

with small bordered pits, e.g. in *Bourreria*, *Echium*, *Ehretia* p.p., and *Rochefortia*, or with simple pits, the pits more numerous on the radial than on the tangential walls. Septate in some species of *Cordia*, *Ehretia*, *Patagonula*, and *Saccellium*. Walls thin to thick. With spiral thickening in some species of *Ehretia* (1206) and *Lithospermum* (2158). Sometimes storied in *Cordia*, e.g. *C. suaveolens* Bl. Mean length 0·7–1·9 mm. **Vasicentric tracheids** often present in *Ehretia*. Small **intercellular canals** of the traumatic type often present in *Cordia*.

ANOMALOUS STRUCTURE

A furrowed xylem-mass with phloem in the depressions recorded by Solereder in *Tournefortia hirsutissima* Linn.

ROOT

A red substance (alkannin) is present in the roots of many members of the family. An account of the formation of the red pigment in the root of *Alkanna tinctoria* Tausch. has been given by Eriksson-Helsingfors (648). The pigment always arises in the cells in which it occurs, and does not diffuse through the cell walls. In the root of the seedling plant, the red pigment first appears in the epidermal cells and root hairs. The epidermis and cortex are cast off during the subsequent development of the root, after which the outermost of the remaining layers of cells becomes suberized, and pigment is formed in the cells. It is stated, however, that the suberized pigment cells are not part of the normal cork, the latter being produced on the inside of the pigmented layer after the colouring matter has been formed. The pigment also arises in association with splits along the medullary rays and other pathological cavities in the root. The author concludes that pigment formation is a wound reaction.

TAXONOMIC NOTES

Solereder (2158, p. 627) pointed out that the genus formerly known as *Zombiana* was doubtfully to be included in the Myoporaceae. It has since been shown by Hutchinson (1113A) that the plant known as *Zombiana africana* Baill. is in reality *Rotula aquatica* Lour., a member of the Boraginaceae. The following characters of *R. aquatica* cited by Solereder agree quite well with those exhibited by other members of the Boraginaceae. In the leaf, the isobilateral lamina; simple, uniseriate hairs; the ranunculaceous stomata present on both surfaces; the petiole containing a median and 2 smaller lateral vascular bundles; the cluster crystals in the mesophyll. In the stem, the sub-epidermal cork; the isolated strands of pericyclic fibres; the closed xylem cylinder traversed by uniseriate rays; the ground-tissue of the xylem consisting of occasionally septate fibres with simple pits.

ECONOMIC USES

The most important timber-producing genus is *Cordia*, with woods varying from light to hard and heavy and from pale to dark brown. The pale-coloured woods are usually general utility timbers, e.g. the Indian *C. myxa* Linn.; the dark-coloured ones are often handsomely streaked and are primarily cabinet woods, e.g. the Bocote of Mexico, *C. gerascanthoides* H. B. et K. and the Ziricote of Guatemala and British Honduras, *C. dodecandra* DC. *Patagonula americana* Linn. produces an extremely durable wood of a similar character.

Alkanet Root, derived from *Alkanna tinctoria* Tausch., yields a red dye. The plant occurs chiefly in the Mediterranean region. The dried roots have the form of tapering, reddish-purple pieces, usually 10–15 cm. or occasionally up to 50 cm. long and 2–5 cm. thick, often spirally twisted or curved. Rootstock bearing the remains of hairy leaf bases. Internal tissues of the root frequently fissured. For particulars of the mode of formation of the colouring matter in the root see under 'Root' (p. 953). The roots of various other members of the Boraginaceae have been substituted for the genuine article, e.g. *Onosma echioides* Linn. and *Macrotomia cephalotes* Boiss. Alkanet should not be confused with the root of the Henna plant (*Lawsonia alba* Lam.), family Lythraceae (see p. 654).

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Alkanna,* Anchusa,* Arnebia, Asperugo, Borago,* Caccinia,* Cerinthe,* Cordia,* Cynoglossum,* Echium,* Ehretia,* Eritrichium, Halgania, Heliotropium,* Lappula, Lindelofia,* Lithospermum,* Lycopsis, Macrotomia,* Mertensia,* Moltkia,* Myosotis,* Nonnea, Omphalodes,* Onosma,* Paracaryum,* Patagonula, Pulmonaria,* Rotula, Sericostoma, Symphytum,* Tournefortia, Trichodesma.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Auxemma, Bourreria, Cordia, Echium, Ehretia, Patagonula, Pteleocarpa, Rochefortia, Saccellium, Tournefortia.

LITERATURE

(i) *On General Anatomy*

Bailey **72**, Betts **189**, Bider **196**, Brandt **257**, **258**, Chodat and Carisso **405**, Chodat and Vischer **403**, Eriksson-Helsingfors **648**, Evenari (Schwarz) **665**, Hutchinson **1113A**, Jodin **1182**, Kienholz **1236**, Sabnis **1977**, Sayeedud-Din **2013**, Starr **2188**, Thompson **2254**, Tobler **2267**.

(ii) *On Wood Structure*

Almeida **23**, de Bastos **147**, Benoist **170**, den Berger **182**, Burgerstein **312**, Chalk **352**, Cozzo **494**, Dadswell **525**, Desch **574**, Giordano **786**, Howard **1088**, Hyde **1117**, Janssonius **1154**, Kanehira **1206**, **1209**, Metcalfe **1496**, Pearson and Brown **1679**, Pereira **1687**, Pfeiffer, H. **1712**, Pfeiffer, J. Ph. **1713**, Record **1780**, **1783**, **1787**, **1800**, **1801**, **1809**, **1825**, **1843**, **1851**, Record and Hess **1886**, **1892**, Record and Mell **1894**, Thompson **2254**, Williams **2430**.

196. CONVOLVULACEAE

(FIG. 91 on p. 402; FIG. 221 on p. 952; FIG. 222 on p. 956; FIG. 223 on p. 958; FIG. 224 on p. 962)

SUMMARY

GENERAL

The most familiar temperate members of this widely distributed family are the Bindweeds (*Calystegia* and *Convolvulus*), but many of those in warmer climates are far more woody. Gates (749) has described how the normally herbaceous stem of '*Merremia gemella* (Burm.) Hallier' was found to become quite woody and as much as 20 mm. in diameter in the conditions prevailing in a warm swamp. Most members of the family possess twining stems, but a few are xeromorphs with reduced leaves. Others again are provided with tuberous underground portions (*Ipomoea*). Flattened stems occur in *Pharbitis hederacea* Chois., the morphology of which has been investigated by Yamaguchi (2480), who concluded that the flattened organ represents a normal axis rather than a compound structure formed by the fusion of separate parts.

Since the Nolaneae, as understood by Bentham and Hooker, differ in certain respects from a majority of the family, they have been treated separately on p. 961. This applies also to *Cuscuta*, but here the differences are mainly correlated with the parasitic mode of life exhibited by this genus. The clothing **hairs,** especially those consisting of long terminal and 1 to several short stalk cells, as well as the 2-armed trichomes, are somewhat characteristic of the family. One of the most important anatomical features is the occurrence of **intraxylary phloem** in all genera except *Cuscuta*. The **petiole** exhibits a median, arc-shaped, bicollateral, vascular strand in transverse sections through the distal end, usually accompanied by subsidiary bundles. The **xylem** in the axis nearly always constitutes a closed cylinder from an early stage. The first-formed vessels are thin-walled and arranged in very definite radial rows; those formed later on are larger in diameter and often solitary. **Anomalous structure** of various kinds is fairly common. These include the occurrence of interxylary phloem in the stem, and of a complex stelar structure in the underground portions of tuberous rooted species. **Secretory cells,** either solitary or in vertical rows, are fairly widespread in both leaf and stem, but often less conspicuous than might be anticipated from statements in the literature.

Leaf

Dorsiventral or isobilateral. Isobilateral structure dominant in *Breweria*, *Cladostigma*, *Convolvulus*, *Cressa*, *Evolvulus*, *Hildebrandtia*, *Seddera*, *Stylisma*; exceptional in tall species; absent from the smallest forms with leathery leaves. Leaf of *Evolvulus alsinoides* Linn. figured as dorsiventral by Dastur and Saxton (543), but described and figured as isobilateral in the same species by Sayeedud-Din (2010). This discrepancy suggests that the mesophyll may be plastic in this species. Dorsiventral structure well defined, owing to the presence of spongy tissue with abundant intercellular spaces, in the leathery leaves of *Breweria* (some species), *Dicranostyles*, *Erycibe*, *Humbertia*, *Lysiostyles*, *Maripa*, *Neuropeltis*. A cylinder of palisade parenchyma surrounding a central mass of large-celled tissue with veins embedded in it recorded by Solereder in '*Ipomoea pedata* Hochst. et Steud.' and in species of *Wilsonia* with fleshy leaves. Collenchymatous spongy tissue recorded in *Jacquemontia*. **Hairs** (Figs. 222 and 224 A–B) include glandular and non-glandular types. The simple type with a long terminal cell as in Fig. 222 A occurs in *Aniseia*, *Calystegia*, *Convolvulus*, *Ipomoea*, *Jacquemontia*, *Merremia*, *Operculina*, *Polymeria*, *Porana*. Two-armed hairs such as those in Fig. 222 B and C together with closely related forms recorded in *Bonamia*, *Breweria*, *Cardiochlamys*, *Cladostigma*, *Convolvulus*, *Cressa*, *Dichondra*, *Dicranostyles*, *Erycibe*, *Evolvulus*, *Hildebrandtia*, *Humbertia*, *Hygrocharis*, *Jacquemontia*, *Lysiostyles*, *Maripa*, *Neuropeltis*, *Porana*, *Prevostea*, *Rapona*, *Seddera*, *Stylisma*, *Wilsonia*. Y-shaped hairs stated to occur in *Cardiochlamys*, *Evolvulus*, *Falkia*, and T-shaped types

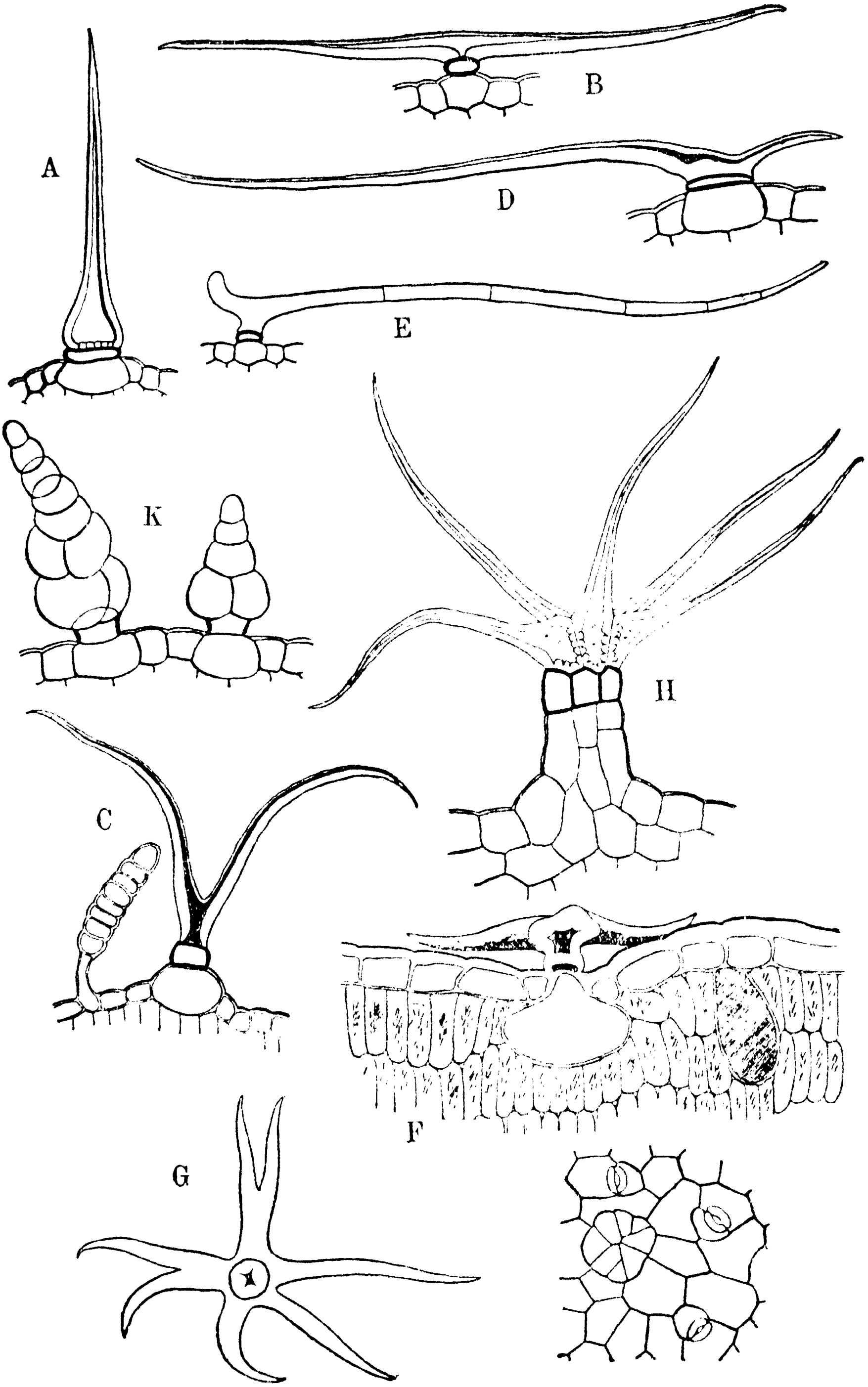


Fig. 222. *CONVOLVULACEAE*

Hairs of: A, *Ipomoea* sp.; B, *Dichondra repens* Forst.; C, *Bonamia* sp.; D, *Evolvulus villosus* R. et P.; E, *Maripa passifloroides* Spruce (corolla); F–G, *Jacquemontia* (*Convolvulus*) *jamaicensis* H. Hallier; H, *Ipomoea contorquens* Choisy; J, *Maripa passifloroides* Spruce; K, *Cardiochlamys madagascariensis*

in *Lysiostyles*. Reduced 2-armed hairs (Fig. 222 D), 2-armed septate types (Fig. 222 E) and branched forms (Fig. 222 F, G, H) also occur. Glandular hairs widely distributed, varying in the length of the stalks and in the shape and number of cells in the heads in different genera and species (Fig. 222 C, K, J). Glandular shaggy hairs, similar to those at the base of the stamens in some of the Convolvulaceae, recorded on the vegetative organs of a few species of *Ipomoea*. **Extra-floral nectaries,** consisting of peltate glandular hairs arranged in special grooves or flask-shaped cavities, recorded at the base of the leaf or on the petiole in species of *Calonyction* and *Ipomoea*. **Cuticle** usually thin, sometimes striated. **Epidermis** consisting of cells with straight or sinuous anticlinal walls; frequently convexly arched or tending to be papillose. True **hypoderm** not recorded, but epidermis becoming locally 2-layered in species of *Dicranostyles*, *Erycibe*, *Ipomoea*, *Lysiostyles*, *Maripa*. **Stomata** commonly present on both surfaces both in dorsiventral and isobilateral leaves; mostly rubiaceous, but cruciferous types also recorded in species of *Breweria*, *Cladostigma*, *Erycibe*, *Evolvulus*, *Hildebrandtia*. Ranunculaceous stomata much less frequent, but occurring, for example, in *Cressa*. **Mesophyll** sometimes including sclerenchymatous fibres in the form of extensions from the sheaths around the veins. Fibres sometimes spreading out beneath the epidermis, e.g. in species of *Dicranostyles*, *Erycibe*, *Humbertia*, *Lysiostyles*, *Maripa*, *Prevostea*. Rows of very characteristic 'spicular cells' (Fig. 224 C) occur sporadically in the palisade and spongy portions of the mesophyll, particularly in *Ipomoea* and occasionally in the same or other parts of the leaf in a few other genera. Vascular bundles of the **veins** bicollateral; surrounded by a closed sheath or accompanied by arcs of sclerenchyma. Variations in this character said to be valuable for the identification of species. Veins provided with green bundle sheaths in *Breweria latifolia* Benth., *Convolvulus microphyllus* Sieb., and *Cressa cretica* Linn.; embedded in the mesophyll in species of *Convolvulus*, *Cressa*, and *Ipomoea* examined by Sabnis (1977), but the larger bundles in *Breweria latifolia* described as vertically transcurrent by the same author. **Petiole** of *Calystegia*, *Convolvulus*, and *Ipomoea* (Fig. 223 B–D), in transverse sections through the distal end, exhibiting a median, bicollateral arc of xylem and phloem, usually accompanied by a few isolated bundles at either end of the arc. Thick-walled **latex canals** (see also 'Axis') in the leaf recorded only in the veins of *Dichondra*. Rows of **secretory cells** (see also 'Axis'), with milky contents when fresh, but becoming coloured yellow or brown in herbarium material, associated with the vascular bundles of the veins in the midrib or elsewhere in the leaf in numerous genera and species; sometimes not easy to detect in mature material owing to compression of the cells and the disappearance of their contents. Similar but isolated cells are also to be found in the mesophyll, particularly at the boundary between the palisade and spongy parenchyma. The presence of secretory cells is said in some instances to have been demonstrated in the cotyledons even when not visible in mature material, e.g. in species of *Argyreia*, *Breweria*, *Cardiochlamys*, *Cladostigma*, *Convolvulus*, *Dicranostyles*, *Erycibe*, *Evolvulus*, *Humbertia*, *Maripa*, *Neuropeltis*, *Porana*, *Prevostea*. Secretory cells absent, even from the cotyledons in *Seddera*. The size, shape, frequency, and distribution of the secretory cells, whether solitary or in rows, is to some extent valuable in the identification of genera and species. Tanniniferous epidermal cells recorded in *Evolvulus alsinoides* by Sayeedud-Din (2010). **Crystals** include small, acicular, and other types, as well as large solitary or clustered forms. Acicular crystals sometimes occur in idioblasts in the mesophyll in species of *Bonamia*, *Calystegia*, *Ipomoea*, *Lepistemon*, and smaller ones occupy compartments in septate palisade cells in species of *Ipomoea*. Abundant cluster crystals recorded by Maire (1419) in *Convolvulus dryadum* Maire and around the vascular bundles in *Brewcria latifolia* Benth. by Sabnis (1977) and in *Evolvulus alsinoides* by Sayeedud-Din (2010). Cluster crystals seen at Kew in the 'cortical' region of the petiole in *Convolvulus floridus* Linn. Large solitary crystals present in the vein's of species of *Maripa* and *Rapona*.

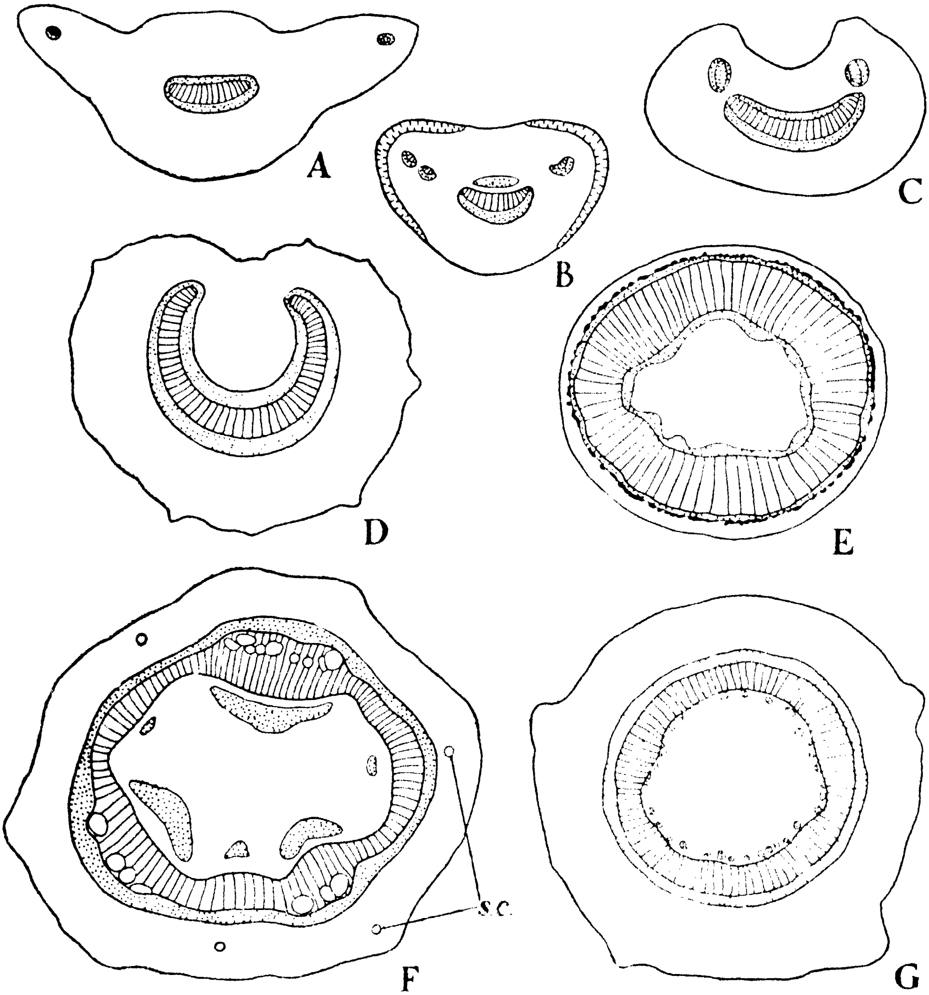


FIG. 223. *CONVOLVULACEAE*

A, *Nolana tenella* Lindl. Petiole × 16. B, *Convolvulus floridus* Linn. Petiole × 20. C, *Calystegia sepium* (L.) R. Br. Petiole × 14. D, *Ipomoea purpurea* Roth. Petiole × 20. E, *Convolvulus floridus* Linn. Stem × 9. F, *Calystegia sepium* (L.) R. Br. Stem × 16. G, *Nolana tenella* Lindl. Stem × 14.

s.c. Secretory canal.

Anatomical differences between 'sun' and 'shade' leaves of '*Ipomoea pes-caprae* Sweet' have been described by Kienholz (1236). The leaves of the 'sun' form are thicker and more fleshy than those of the 'shade' form, the palisade tissue on the lower side of the leaf being less well developed in the latter. The stomata of the 'sun' leaves possess a special mechanism for opening and closing. Stomata are more numerous in the 'sun' than in the 'shade' leaf, but hydathodes, on the other hand, are more numerous in the 'shade' than in the 'sun' leaf.

AXIS

STEM (Fig. 223 E–F)

Cork usually superficial in origin; described by Solereder as arising sporadically in any tissue from the epidermis to the pericycle or, in *Hewittia bicolor* Wight. et Arn., even deeper. Cork cells thin-walled in species of *Breweria*, *Ipomoea*, *Rivea*, *Seddera*, *Wilsonia*, but some of them sclerosed in species of *Erycibe*, *Maripa*, *Operculina*. Primary **cortex** commonly containing collenchyma, and often assimilatory tissue, especially in species with reduced leaves. An **endodermis** containing chloroplasts recorded in young stems of '*Ipomoea pes-caprae* Sweet' by Mullan (1571). **Pericycle** usually including rather scanty sclerenchyma, presumably because the climbing habit needs flexibility; a discontinuous ring of rather thin-walled fibres noted at Kew in species of *Calystegia*, *Convolvulus*, and *Ipomoea*; a ring of fibres recorded by Solereder in species of *Erycibe* and *Porana* and a subcontinuous ring in *Convolvulus dryadum* R. Maire by Maire (1419). Pericycle including closely placed groups of stone cells in *Cressa cretica* Linn., *Convolvulus glomeratus* Chois., and *C. microphyllus* Sieb., solitary and very small groups of stone cells in *Breweria latifolia* Benth., and a composite ring of stone cells in *Ipomoea sindica* Stapf recorded by Sabnis (1977). Secondary **phloem** said to be devoid of sclerenchyma except sometimes in *Dicranostyles* and *Humbertia*. **Xylem** in the form of a cylinder traversed only by narrow rays in species of *Calystegia*, *Convolvulus*, and *Ipomoea* examined at Kew. Vessels of the primary xylem usually relatively small and arranged in very definite radial rows, this feature being particularly marked in species of *Calystegia* and *Convolvulus*. Later-formed vessels (Fig. 223 F) in herbaceous species belonging to the same genera very much larger and confined to certain arcs of the xylem cylinder. Later-formed vessels in *Ipomoea* likewise larger than the primary vessels, but solitary and more evenly distributed amongst the thick-walled elements of the fibrous ground-mass of the xylem. Primary xylem in the woody species *Convolvulus floridus* Linn., like the herbaceous species, also provided with radial rows of crowded vessels up to about 60 μ in radial diameter. Vessels of the secondary xylem in young twigs of *C. floridus* including rather infrequent, mostly solitary (occasionally in oblique pairs or tangential groups of 3), circular to slightly oval vessels, up to about 75 μ in radial diameter, embedded in a ground-mass of polygonal, thick-walled fibres with small, slit-shaped, inconspicuously bordered pits. Vessel perforations not always easy to observe, but simple wherever seen.

Strands of **intraxylary phloem** (those in *Convolvulus dryadum* R. Maire described by Maire (1419) as sufficiently close to form an almost continuous ring) occur in all investigated members of the family except *Cuscuta*, which is described separately on p. 961; often containing rows of secretory cells and chambered fibres filled with cluster crystals; the internal margin sometimes supported by fibres, or, more rarely, arcs of sclerenchyma. Intraxylary phloem sometimes of secondary origin in *Calystegia sepium* (L.) R. Br., some of the strands being bounded externally by a well-defined cambium in this species. Xylem groups occasionally developed in association with the intraxylary phloem, thus converting the latter to inversely orientated **medullary bundles,** e.g. in species of *Argyreia*, *Erycibe*, *Hewittia*, *Neuropeltis*, *Prevostea*, *Rivea*. Medullary bundles become enlarged through the activity of a cambium in *Erycibe* sp. **Pith** usually unlignified, but lignified, for example, in *Breweria latifolia* Benth.; commonly including stone cells, the latter sometimes in the form of transverse partitions. **Laticiferous canals** noted at Kew in the cortex of *Calystegia* and *Convolvulus* and in the cortex and phloem of *Ipomoea*; similar elements also recorded by Solereder in *Dichondra*. **Secretory cells** (see also 'Leaf') filled with milky contents when fresh, but the latter becoming colourless, yellow, or brown when dried, arranged in long rows in the pith, primary cortex, and phloem of many, but by no means all, genera and species. Similar but solitary cells also occur in the primary cortex and pith of some species. Cluster **crystals** seen in the cortex and pith of one species of *Ipomoea*, and solitary cubical and prismatic crystals in vertical rows of cells in the cortex of *Convolvulus floridus*, but none observed in the other genera and species examined at Kew; clustered crystals recorded by Sabnis (1977) in the cortex and pith, and solitary ones in the phloem of *Breweria latifolia* Benth., and cluster crystals in the cortex and pith of '*Ipomoea pes-caprae*' by Mullan (1571).

WOOD (Fig. 91 F, FIG. 221 A–B)

Not a great deal can be added to the account given by Solereder, of which the following is mainly a summary.

Vessels extremely small (less than 25 μ mean tangential diameter) to large (more than 200 μ) in some lianes, exclusively solitary in *Convolvulus* and *Porana*, perforations simple, intervascular pitting mostly large, alternate, pits to ray and wood parenchyma similar in size and shape, often simple. Mean member length (*Convolvulus*) about 0·23 mm. (1497). **Parenchyma** sometimes abundant; very sparse and limited to scanty paratracheal with some scattered cells in material examined of *Convolvulus* and *Porana*. **Rays** narrow; up to 2 cells wide in *Convolvulus* and *Porana* and composed almost entirely of square to upright cells. **Fibres** with bordered pits, equally numerous on both radial and tangential walls; mean length (*Convolvulus*) 0·85 mm. (1497).

RHIZOME

Rhizome of *Convolvulus dryadum* R. Maire described by Maire (1419) as similar in structure to the aerial stem, but with the xylem more fully developed and including several annual rings. Rhizome of the same species also differing from the aerial stem in having a more interrupted ring of fibres in the **pericycle.** Strands of **laticiferous cells** also recorded by Maire in the cortex, phloem, and pith.

ROOT

A suberized **endodermis** recorded in *Convolvulus dryadum* R. Maire by

Maire (1419). Mullan (1571) has recorded in '*Ipomoea pes-caprae* Sweet.' **lenticels** at the proximal ends of old roots; **cork,** initially superficial, but later arising more deeply in the cortex; large air spaces in the inner **cortex;** thin-walled cells with laticiferous contents.

ANOMALOUS STRUCTURE

(i) Xylem partly or wholly unlignified in a few species of *Breweria*, *Convolvulus*, *Exogonium*, *Ipomoea*. (ii) Xylem in certain lianes chiefly developed around the vessels which are restricted to 2 or 3 radii. (iii) Xylem occasionally slightly furrowed, e.g. in *Merremia*. (iv) Successive growth-rings (interxylary phloem) common in woody species of *Argyreia*, *Calonyction*, *Convolvulus*, *Erycibe*, *Hewittia*, *Ipomoea*, *Maripa*, *Merremia*, *Porana* (Fig. 91 F), *Rivea*. (v) Secondary, accessory vascular bundles, usually arising in the parenchymatous ground-tissue of the xylem, occur especially in species with fleshy roots and of which the aerial parts die down annually. For further details see 'Economic Uses', p. 963, and Fig. 224 D.

NOLANEAE

Herbs belonging to the genera *Alona*, *Bargemontia*, *Dolia*, and *Nolana*, which constitute the tribe Nolaneae in the Bentham and Hooker system, differ in certain respects from most of the Convolvulaceae, and it is open to question whether these genera should be treated as a tribe of the Convolvulaceae, or as a distinct family, or whether they should be included in the Solanaceae (see 'Taxonomic Notes', p. 963).

The non-glandular **hairs** differ from those of most of the Convolvulaceae in always being multicellular, the commonest type being simple, uniseriate trichomes (particularly in *Nolana*) together with branched forms such as those in Fig. 224 A–B. Glandular hairs, with stalks consisting of 1 or 2 cells and unicellular or multicellular ellipsoidal heads, recorded in *Alona* and *Nolana*. **Stomata** in at least certain species of *Nolana*, present on both surfaces; tending to be, although not invariably, cruciferous. **Petiole** of *N. tenella* Lindl. (Fig. 223 A), in transverse sections through the distal end, exhibiting a median, bicollateral, slightly arc-shaped vascular strand, accompanied by smaller bundles in the wings. The structure thus resembles that of the petiole of other members of the Convolvulaceae not included in the Nolaneae. In the axis (Fig. 223 G) the **pericycle** commonly contains isolated groups of sclerenchyma. **Intraxylary phloem** is always present, usually in the form of small strands. **Secretory cells** present in the parenchymatous tissues of the stem. **Crystal-sand** noted at Kew in *Nolana*, and recorded in other members of the Nolaneae by Mirande (1539).

CUSCUTEAE

The parasitic genus *Cuscuta* consists of small twining herbs which grow on a variety of plants, including economically important crops such as clover and lucerne. Although usually classified with the Convolvulaceae, they differ to some extent from typical members of the family. This is not surprising in view of their parasitic mode of life and relatively small size. The **hairs,** when present, are mostly simple, consisting of 1 or 2 cells. The leaves are reduced to scales and contain little or no chlorophyll, whilst the minute vascular bundles are usually embedded in a homogeneous **mesophyll.** Palisade tissue is rare in a few species. **Stomata** are said to be surprisingly numerous in some species. **Secretory cells** are to be found in the primary cortex, pericycle, and, more rarely, the pith of the axis. The **vascular system** of the **axis,** which consists mainly of primary tissues, may reasonably be regarded as a reduced form of the type which occurs in more typical members of the Convolvulaceae. There are minute groups of vessels accompanied by phloem strands, which are sometimes so closely packed that they almost constitute a closed ring, but in other cases they are rather more widely separated. The phloem is generally more fully developed than the xylem, and not infrequently occurs in the form of strands, unaccompanied by vessels, interspersed between other collateral groups of phloem and xylem. The protoxylem of certain species has been observed to break down to form an irregular canal at the inner margin of each of the vascular bundles. No trace of **intraxylary phloem**

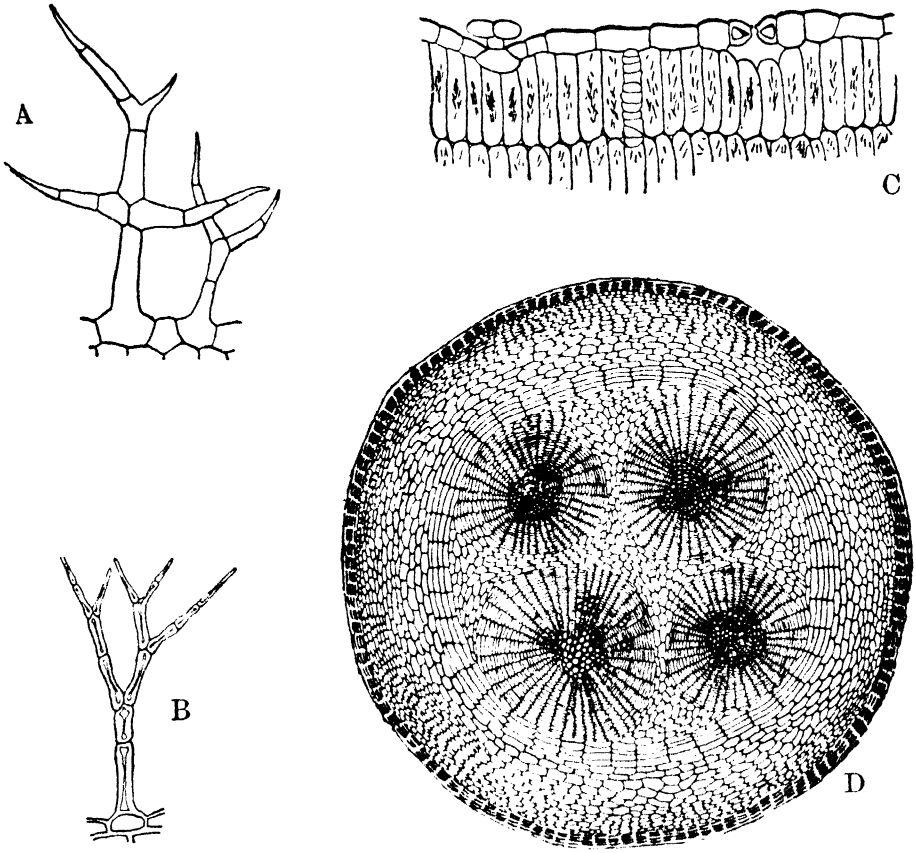


FIG. 224. *CONVOLVULACEAE* (*including NOLANACEAE*)

A, Branched trichome of *Dolia tomentosa* Benth. et Hook. B, Branched trichome of *Alona dubia* Philippi. C, Transverse section through the upper half of the leaf of *Ipomoea bahiensis* Willd., with a row of 'spicular cells'. D, Transverse section through a root of *Convolvulus scammonia* Linn., at a stage in which cleavage of the xylem into 4 portions, and the development of a cambial ring around each of them, have taken place. A and C by Solereder. B after Schlepegrell. D after Dutailly.

has been detected in any species, but this is not altogether surprising in stems which are so very much reduced. It may be that a careful search amongst a large number of species would reveal remnants of intraxylary phloem in some of them, but this remains to be seen. The vascular system is sometimes surrounded by a sheath of cells with abundant protoplasmic contents. Variations in the intercellular system of the stem have been used as an aid in the identification of species, but this subject needs further investigation. The taxonomy, development of the embryo-sac, and related phenomena in *Cuscuta* have been described by Smith (2144).

TAXONOMIC NOTES

It is implied above (p. 961) that the Nolaneae are so much like the Convolvulaceae in anatomical structure that they can best be treated as a tribe rather than as a distinct family. A somewhat different view has, however, been expressed by Mirande (1539), who points out that the intraxylary phloem in *Nolana* and its allies arises in the hypocotyl. This applies also to the Solanaceae but not to the Convolvulaceae, where the intraxylary phloem is said to arise in the stem above the level of the hypocotyl. It is also interesting to note that crystal-sand occurs in the Nolaneae, a feature which is characteristic of the Solanaceae rather than of the Convolvulaceae. For these reasons Mirande concluded that the Nolaneae should be included in the Solanaceae rather than the Convolvulaceae. It was also suggested as a possible alternative that it might be preferable, on the grounds of floral morphology, to treat them as a separate family between the Boraginaceae and Solanaceae.

ECONOMIC USES

One of the best-known economic products is the Sweet Potato, which consists of the tubers of *Ipomoea batatas* Poir., a plant widely cultivated in tropical countries. The tubers are usually regarded as roots, but were believed by Kamerling (1205) to be more in the nature of stems. They have been described anatomically by several authors including McCormick (1463) and Artschwager (39). The primary structure of the larger roots is pentarch or hexarch. In the young root a broad, somewhat spongy cortex is bounded internally by a distinct endodermis. Secondary thickening is at first of the type which is normal in roots, but later on separate strands of xylem and phloem are laid down in the ground-tissue where they become partly or wholly surrounded by secondary cambium. Transverse sections of mature tubers exhibit a parenchymatous, amyliferous ground-tissue with strands of xylem, consisting of 1 to several vessels with or without accompanying phloem, embedded in it. Other strands consist only of phloem. The larger vessels become filled with tyloses. The tuber is traversed radially by root traces connected with the lateral rootlets. In some varieties there are narrow invaginations of the main cambium ring. The cortex of the mature root consists mostly of secondary amyliferous tissue with radial rows of sieve tubes and rather inconspicuous laticiferous elements embedded in it. According to Artschwager, the parenchymatous ground-tissue of certain varieties breaks down in storage and forms polyhedral cavities lined with the partly disintegrated tissue. The starch of the Sweet Potato is sometimes substituted for Arrowroot, which consists of the starch of *Maranta arundinacea* Linn. (family Marantaceae).

Jalap, used in medicine as a powerful purgative, consists of the dried tubers of *Ipomoea purga* Hayne from the Mexican Andes. The fundamental structure and mode of secondary thickening resembles that of the Sweet Potato. Microscopical characters include the abundant 2–6 compound and occasional simple starch grains, the individual grains being up to about 60 μ in diameter; the secretory cells in the phloem with yellowish-brown contents stained yellow by iodine and red by tincture of alkanna; the cluster crystals of calcium oxalate about 10–30 μ in diameter; the occasional stone cells and the absence of fibres.

The so-called Mexican Jalap, with similar medicinal properties and also obtained from the Andes, is the product of *Ipomoea orizabensis* (Pellet) Ledanois. In this species the mostly compound starch grains consist of 2–5 components, the individual grains being up to 35 μ in diameter; the numerous cluster crystals of calcium oxalate, about 15–45 μ in diameter, are accompanied by occasional, solitary, prismatic crystals; the greyish-brown secretory cells are stained deep yellow by iodine. Tampico Jalap, derived from *Ipomoea simulans* Hanbury, is sometimes substituted for true Jalap. Another substitute is Brazilian Jalap derived from *Ipomoea tuberosa* Linn., sometimes erroneously called *Piptostegia pisonis* Mart.

Scammony root (Fig. 224 D), obtained from *Convolvulus scammonia* Linn., is now seldom used. In this species the starch consists of 2–4 compound grains with a V-shaped hilum, the larger grains being 20–25 μ in diameter.

Kaldana, or Pharbitis seeds, consists of the seeds of *Ipomoea hederacea* Jacq. from India, and possesses properties similar to those of Jalap. The histology and chemistry of the seeds have been described by Kassner (1222).

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Alona, Aniseia, Argyreia, Bargemontia, Breweria, Calonyction, Calystegia,* Cardiochlamys, Cladostigma, Convolvulus,* Cressa, Cuscuta,* Dichondra, Dicranostyles, Dolia, Erycibe, Evolvulus, Exogonium, Falkia, Hewittia, Hildebrandtia, Humbertia, Hygrocharis, Ipomoea,* Jacquemontia, Lepistemon, Lysiostyles, Maripa, Merremia, Neuropeltis, Nolana,* Operculina, Pharbitis, Polymeria, Porana, Prevostea, Rapona, Rivea, Seddera, Stylisma, Wilsonia.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

The few facts recorded under 'Wood' are based on 2 species of Convolvulus, Nördlinger's sections of Porana and Solereder's description of the following genera: Convolvulus, Cressa, Dicranostyles, Erycibe, Ipomoea, Lysiostyles, Maripa, Neuropeltis, Wilsonia.

LITERATURE

(i) *On General Anatomy*

Artschwager **39**, Dastur and Saxton **543**, Gates **749**, Kamerling **1205**, Kassner **1222**, Kienholz **1236**, Maire **1419**, McCormick **1463**, Mirande **1539**, Mullan **1571**, Sabnis **1977**, Sayeedud-Din **2010**, Smith, B. E. **2144**, Yamaguchi **2480**.

(ii) *On Wood Structure*

Greiss **817**, Metcalfe **1497**, Pfeiffer, H. **1712**, Record **1843**, **1851**.

197. SOLANACEAE

(FIG. 225 on p. 966; FIG. 226 on p. 968; FIG. 227 on p. 970)

SUMMARY

(i) GENERAL

This widely distributed family includes herbs and woody plants. The numerous **hairs** include a considerable diversity of glandular and non-glandular forms (Fig. 225). The leaf is usually dorsiventral, but isobilateral in certain species. The most outstanding anatomical feature is the universal occurrence of **intraxylary phloem** in the axis and **petiole,** the latter being provided with an arc-shaped vascular strand accompanied by a few smaller bundles. The **stomata** are, in many cases, ranunculaceous, but cruciferous and caryophyllaceous types occur in certain genera. The origin of the **cork** is superficial or deep-seated in different genera and species. The **pericycle** usually contains strands or a loose ring of fibres. **Interxylary phloem** has been recorded in the rhizomes and root of a few species. Numerous solitary and cluster **crystals** as well as crystal-sand occur in both leaf and stem, several types often being mixed together. The morphology and mode of secretion of crystals in the Solanaceae has been described by Kreusch (1281) and Lubenau (1398).

(ii) WOOD

Vessels very small to medium-sized, and few to extremely numerous, very variable in arrangement, often with numerous clusters, radial multiples of 4 or more cells common in some species, sometimes with a flame-like (dendritic) or tangential pattern, ring-porous and with spiral thickening in a few species, perforations simple, intervascular pitting alternate, usually large but occasionally minute, pits to parenchyma usually large and elongated; members of medium length to moderately short. **Parenchyma** either scanty paratracheal or predominantly apotracheal, as scattered cells or short uniseriate bands. **Rays** exclusively uniseriate or up to 8 cells wide, often composed entirely of large square or upright cells, but sometimes of small cells and almost homogeneous. **Fibres** typically with simple pits and rather thin walls, but bordered pits and thick walls occur in a few species; thin septa reported in some genera; of medium length to moderately short. Large **radial channels** reported in some species.

LEAF

Usually dorsiventral, but isobilateral in a number of species, e.g. according to Sabnis (1977) in certain species of *Solanum* from desert regions in India. **Hairs** of many kinds occur (Fig. 225). (i) Simple, unicellular trichomes recorded only in *Schizanthus*. (ii) Uniseriate hairs of various kinds widely distributed (Fig. 225 D–F); always 3-celled in *Nicandra physaloides* Gaertn.; with long terminal cells in *Metternichia*; with thickened terminal cells in *Henoonia*. (iii) Variously branched, multicellular hairs (Fig. 225 A, E) recorded in species of *Acnistus*, *Anthocercis*, *Anthotroche*, *Bassovia*, *Cestrum*, *Chamaesaracha*, *Iochroma*, *Juanulloa*, *Lycium*, *Nicotiana*, *Physalis*, *Poecilochroma*, *Scopolia*, *Sessea* (candelabra hairs) (Fig. 225 A), *Solandra*. (iv) Various types of tufted and stellate hairs in species of *Cyphomandra*, *Dunalia*, *Solanum*.

(v) Peltate hairs (Fig. 225 B–C) said to be confined to *Solanum*. (vi) Glandular hairs (Fig. 225 E, F, G, H, J), varying in the length and number of cells in the stalks and in the size and shape of the heads, widely distributed. Hair characters for the identification of different species of *Lycopersicum* have been recorded by Luckwill (1400). **Spines,** composed of elongated, lignified cells, present in certain species of *Solanum*. **Epidermis** sometimes papillose on the upper surface in a few species of *Cestrum* and *Juanulloa*; partly consisting of cells filled with crystal-sand in *Salpichroa rhomboidea* Miers. Cells of the lower epidermis said sometimes to contain chlorophyll in *Datura*. **Stomata** either occurring on both surfaces or confined to the lower side; frequently ranunculaceous, but cruciferous types recorded in *Datura*, *Duboisia* (Fig. 225 H), *Hyoscyamus*, *Jaborosa*, *Solanum*, *Withania*, and caryophyllaceous in species

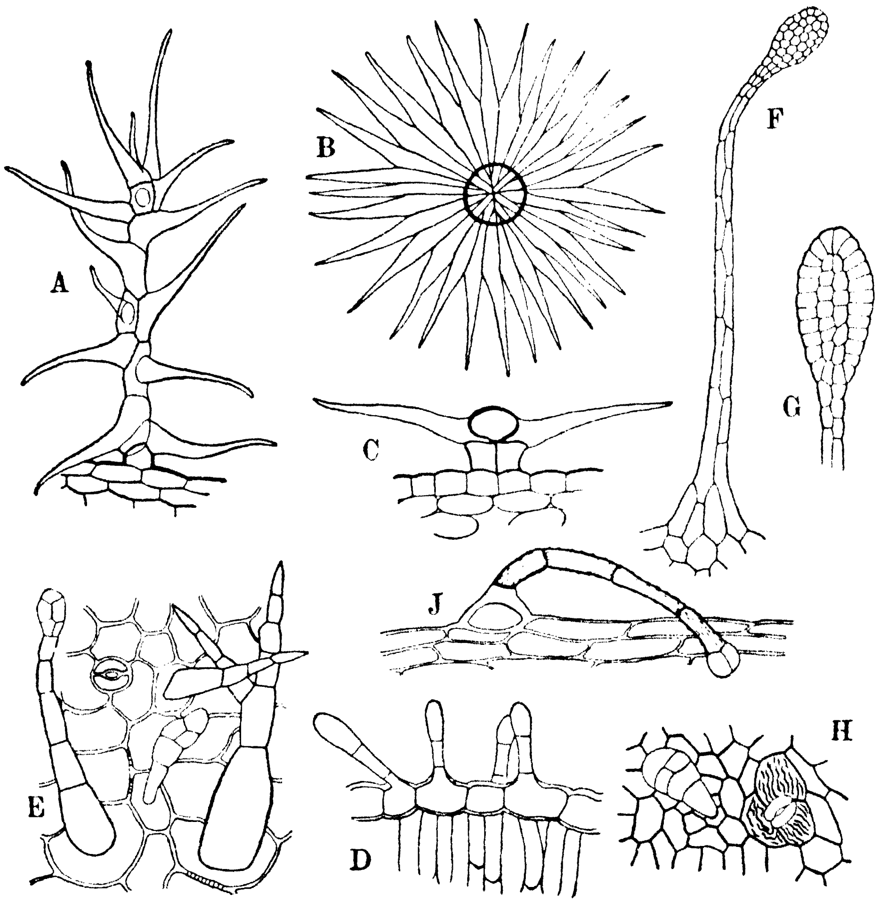


Fig. 225. *SOLANACEAE*

A, Candelabra-hair of *Sessea vestita* Miers. B–C, Peltate hair of *Solanum argenteum* Dun.; B, in surface-view from above, C, in section. D–J, Glandular hairs. D, *Lycium arabicum* Schweinf. E, Leaf-surface of the Folia Nicotianae. F–G, *Schizanthus pinnatus* R. et P., F, showing surface-view of the glandular head, G, glandular head in longitudinal section. H, *Duboisia myoporoides* R. Br. J, *Melananthus fasciculatus* Solered.—A–C and F–J by Solereder, D, after Volkens, E, after J. Möller.

of *Dyssochroma, Juanulloa, Melananthus, Schwenkia.* Comma-shaped depressions stated to occur at opposite ends of the guard cells in *Trianaea.* Stomata situated on projections above the resin-coated leaf surface in *Fabiana.* **Mesophyll** sometimes mucilaginous in *Sclerophylax.* Arm-palisade cells recorded in *Protoschwenkia* and *Schwenkia.* Walls of the palisade cells sometimes strengthened with thickening ridges in *Dyssochroma, Juanulloa, Markea.* Vascular bundles of the smaller **veins** not always accompanied by sclerenchyma. **Petiole** (Fig. 226 B, D, F), in transverse sections through the distal end, exhibiting a median arc-shaped, bicollateral vascular strand, usually accompanied by 1–4 smaller bundles on either side of the grooved adaxial surface, in species of *Atropa, Browallia, Brugmansia, Brunfelsia* (Fig. 226 F), *Capsicum, Cestrum, Cyphomandra, Hyoscyamus, Jaborosa, Lycium, Lycopersicum, Nicandra, Nicotiana, Nierembergia, Petunia, Physalis* (Fig. 226 D), *Salpiglossis, Schizanthus, Scopolia, Solanum, Streptosolen.* Median vascular strand usually rather shallow in the above genera, but deeply crescentic or U-shaped in species of *Cyphomandra, Datura* (Fig. 226 B), and *Lycopersicum.* Median vascular arc somewhat dissected in *Physochlaina orientalis* G. Don. **Crystals** occur in various forms, including solitary and clustered types as well as different kinds of small crystals. Crystal-sand widely distributed, although often more frequent in the stem than in the leaf, recorded in species of *Acnistus, Anthotroche* (sometimes mixed with relatively large crystals), *Atropa, Cacabus, Cyphomandra, Datura, Discopodium, Duboisia, Dyssochroma, Goetzea, Henoonia, Hyoscyamus, Iochroma, Isandra, Jaborosa, Juanulloa, Lycium, Lycopersicum, Markea, Nicotiana, Salpichroa, Salpiglossis, Saracha, Sclerophylax, Scopolia, Solandra, Solanum, Trianaea, Vestia, Withania.* Crystal-sand said to be absent from *Brunfelsia, Cestrum, Fabiana, Melananthus, Nicandra, Nierembergia, Schwenkia.* Small prismatic crystals recorded in species of *Atropa, Capsicum, Datura, Hyoscyamus, Iochroma, Saracha, Triguera, Withania.* The morphology and mode of secretion of crystals in the Solanaceae has been investigated by Kreusch (1281). This author worked particularly with *Atropa belladonna* Linn., *Datura stramonium* Linn., *Hyoscyamus niger* Linn., and other members of the family. It was found that the crystals are not initially secreted in their final form. Small granules are at first deposited in the plasma. These collect in 2 positions which serve as centres for the formation of sphaerites with a covering of plasma. Solitary crystals are then formed from the sphaerites and these in turn give rise to cluster crystals or crystal-sand. If the plants are starved, some of the above stages are omitted, and, in Kreusch's opinion, the exact course of events is determined by the relative proportions of calcium and oxalate ions. Kreusch also observed that most of the crystals in cotyledons are solitary, and not of the same kinds as in mature leaves of the same species. Young flowers are free from crystals, but calcium oxalate is deposited in them when more mature, either in the same or different forms from the crystals in the foliage leaves. The amount of oxalate in the ovary wall increases during the ripening of the fruit.

The morphology and mode of secretion of crystals in *Atropa belladonna, Datura stramonium,* and *Hyoscyamus niger* has also been investigated by Lubenau (1398), whose conclusions agree, in a general way, with those of Kreusch. Lubenau, however, unlike Kreusch, devoted special attention to determining whether the crystals secreted were mono- or trihydric, and showed that trihydric prisms and druses are characteristic of fully mature or decaying leaves, whilst monohydric crystals occur chiefly in young or less mature leaves. Lubenau was also unable to substantiate Kreusch's opinion that crystal-sand in *Atropa* arises from sphaerites. Both Lubenau and Kreusch agree that the deposition of crystals begins at the apex of the leaf and proceeds along the margin to the base, and from the margin towards the midrib. Lubenau, like Kreusch, failed to modify the type of crystals secreted in a given species by exposing the plants to different environmental conditions.

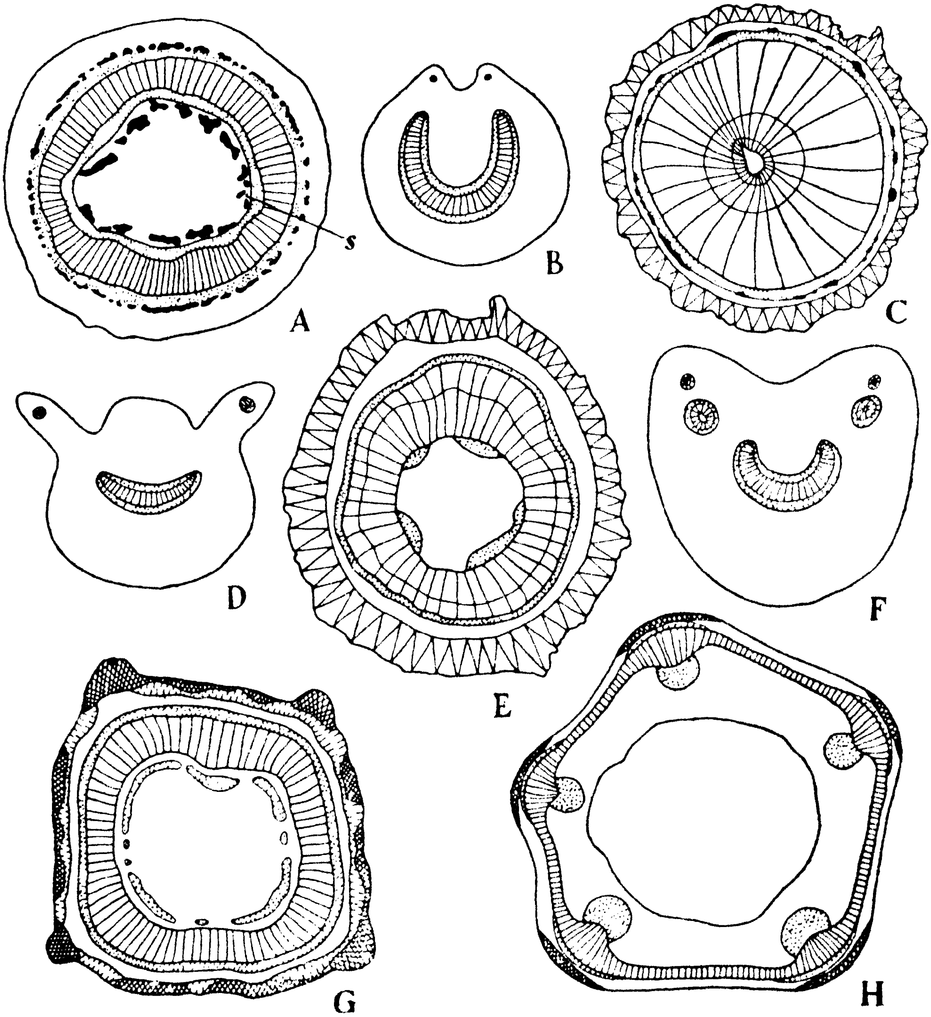


Fig. 226. *SOLANACEAE*

A, *Streptosolen jamesonii* Miers. Stem × 19. B, *Datura tatula* Linn. Petiole × 9. C, *Fabiana violacea* Hort. Stem × 12. D, *Physalis francheti* Mast. Petiole × 20. E, *Lycium chinense* Mill. Stem × 20. F, *Brunfelsia americana* Linn. Petiole × 20. G, *Capsicum annuum* Linn. Stem × 16. H, *Nicandra physaloides* Gaertn. Stem × 6.

s. Stone cells.

Detailed descriptions of the structure of the leaf in a number of species of *Solanum* have been published by Bitter (201).

AXIS

STEM (Fig. 226 A, C, E, G, H)

Cork arising in the epidermis or sub-epidermis in species of *Brugmansia, Brunfelsia, Cestrum, Datura, Duboisia, Fabiana* (Fig. 226 C), *Iochroma, Melananthus, Nicandra, Nicotiana, Nierembergia, Petunia, Physalis, Protoschwenkia, Schwenkia, Solanum, Vestia*; originating near the outer margin of the phloem in species of *Dunalia, Grabowskia, Latua, Lycium* (arising early and specially well developed in this genus) (Fig. 226 E), *Mandragora, Phrodus.* Cork cells usually thin-walled with wide lumina, but some of them with thickenings to the inner tangential wall. Cork including stone cells in species of *Juanulloa, Lycium, Nicotiana, Phrodus, Sessea, Solandra.* Primary **cortex** often collenchymatous in the outer part; including stone cells in some species of *Acnistus, Brunfelsia,* and *Dunalia*; partly differentiated as palisade assimilatory tissue, e.g. in species of *Leptoglossis, Nicotiana, Salpiglossis.* A conspicuous **endodermis** recorded in *Browallia, Nicotiana* (Sabnis 1977), and *Solanum.* **Pericycle** including strands or a loose ring of fibres with thin or thick walls. Occasional stone cells present amongst them. Fibres absent from the pericycle in species of *Lycium, Lycopersicum, Nierembergia, Petunia,* and *Schizanthus* examined at Kew. Secondary **phloem** usually devoid of fibres, but a few rod cells reported in this region in *Datura* and stone cells in *Cestrum.* **Xylem** in the form of a continuous cylinder, traversed by narrow rays in most of the genera and species examined at Kew; dissected by relatively broad rays in *Brugmansia* and *Datura.* Broad rays also occur in the mature secondary xylem in certain other genera (see 'Wood', p. 971). Vessels of the primary xylem tending to be in radial rows; those of the secondary xylem of young stems variously distributed in different genera and species. Vessels with simple perforations. **Intraxylary phloem,** in the form of a continuous cylinder or strands and frequently accompanied by isolated groups or a continuous ring of sclerenchyma (Fig. 226 A), universally present at the periphery of the pith. This does not apply to *Lonchostoma* and *Retzia* which have sometimes been erroneously included in the family. *Retzia* has recently been reinvestigated by Friedel (718). Intraxylary phloem often capable of growing in thickness through the activity of a cambium. Additional phloem strands, penetrating more deeply into the pith, recorded in species of *Atropa, Nicandra, Nicotiana, Solanum.* **Pith** usually unlignified, but some of the cells sclerosed in species of *Brugmansia, Brunfelsia, Discopodium, Duboisia, Dyssochroma, Salpichroa, Sessea.* **Crystals** of the same kinds as those described under 'Leaf' occur very widely. Cluster crystals noted at Kew in the cortex and pith of *Brunfelsia americana* Linn. and crystal-sand in species of *Atropa, Brugmansia, Capsicum, Cyphomandra, Datura, Hyoscyamus, Jaborosa, Lycium, Lycopersicum, Nicotiana, Physalis, Salpiglossis, Scopolia, Solanum.* No crystals seen, but possibly overlooked, in species of *Browallia, Cestrum, Fabiana, Nicandra, Nierembergia, Petunia, Physochlaina* (crystal-sand in the root of this genus), *Schizanthus,* and *Streptosolen.*

Secretory elements. Tannin sacs recorded in *Solandra* sp., in both root and stem. The **developmental anatomy** of the stem, leaf, and flower of

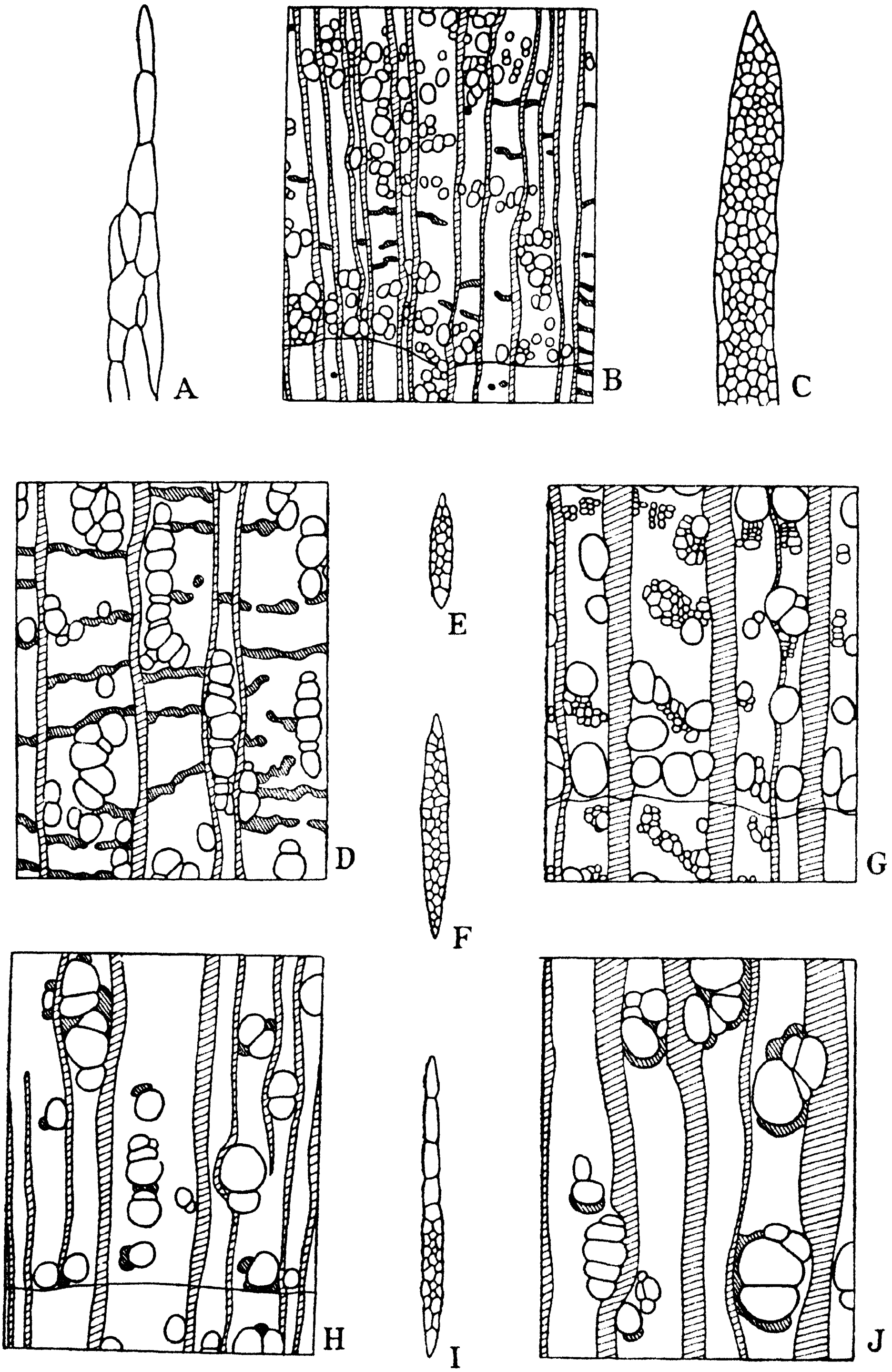


FIG. 227. *SOLANACEAE*

A, *Capsicum asterotrichum* Standley. B, *Lycium acutifolium* E. Mey. C, *Acnistus australis* Griseb. D, *Duboisia myoporoides* R. Br. E, *Grabowskya* sp. F, *Solanum bicolor* Willd. G, *Acnistus australis*

Datura has recently been described by Satina, Blakeslee, and Avery (1998, 1999).

WOOD (Fig. 227)

Vessels very variable in size, commonly ranging from very small (25–50 μ mean tangential diameter) to medium-sized (100–200 μ) even in different species of the same genus, e.g. in *Cestrum* and *Solanum*; mostly small (less than 100 μ); very variable in arrangement, but very commonly with irregular clusters (Fig. 227 J) and frequently with some multiples of 4 or more cells; radial multiples most pronounced in some species of *Brachistus*, *Brugmansia*, *Capsicum*, *Cestrum*, *Duboisia* (Fig. 227 D), and *Nicotiana*; sometimes arranged in loose radial or oblique rows, e.g. in *Athenaea* (Fig. 227 H) and *Lycianthes*, and in distinct oblique groups (dendritic) in *Grabowskia* and *Lycium* (Fig. 227 B); occasionally with a tangential pattern, e.g. in some species of *Acnistus* (Fig. 227 G) and *Solanum*; woods with a dendritic or tangential pattern often with groups of extremely small vessels that look like tracheids or parenchyma in transverse sections (Fig. 227 G); almost entirely solitary in *Fabiana imbricata* R. et P.; mostly 7–30 per sq. mm., more than 100 per sq. mm. in some species of *Fabiana* and *Solanum*; ring-porous in some species of *Acnistus*, *Grabowskia*, *Iochroma*, *Lycium*, and *Solanum*. Spiral thickening observed in *Grabowskia* and *Lycium* and reported by Solereder in *Anthocercis*, *Cestrum*, and *Solanum*; sometimes limited to the smaller vessels. Perforations simple. Intervascular pitting typically moderately large, but small to minute in *Cestrum* p.p., *Nicotiana*, and *Streptosolen*; pits to ray and wood parenchyma usually simple and elongated, but similar in size and shape to the intervascular pitting in *Brachistus*, *Cyphomandra* p.p., *Duboisia*, *Fabiana*, *Grabowskia*, *Lycium*, *Solanum*, and *Streptosolen*. Tyloses rare, but occasionally present, e.g. in *Acnistus*; not abundant. Mean member length 0·3–0·4 mm. **Parenchyma** usually scanty and limited to a few cells or a narrow sheath round each vessel; predominantly apotracheal, as scattered cells or irregular uniseriate bands in *Brachistus*, *Duboisia* (Fig. 227 D), *Fabiana*, *Grabowskia*, *Lycium* (Fig. 227 B), *Nicotiana*, *Nothocestrum*, and *Solandra* and in occasional species of *Solanum*, e.g. *S. vitiense* Seem.; very rare in or absent from some species of *Cestrum*, *Sessea*, and *Solanum*; in widely spaced bands 2–3 cells wide, intermediate between metatracheal and confluent, in *Nothocestrum latifolium* Gray; in isolated groups in *Capsicum asterotricha* Standl., suggesting strands of included phloem, as in *Strychnos*. With large crystalliferous idioblasts in *Grabowskia* and sometimes with crystal-sand in *Solanum*. Strands of 2 or 2–4 cells. **Rays** sometimes of 2 distinct sizes; 1–8 cells wide; exclusively uniseriate or with only occasional biseriate rays in *Cyphomandra*, *Fabiana*, *Lycium* p.p., and *Nothocestrum*; largest (5 or more cells wide) in some species of *Acnistus*, *Brugmansia*, *Capsicum*, *Cestrum*, *Datura*, *Iochroma*, *Lycianthes*, and *Solanum*. Sometimes distinctly more than 1 mm. high, e.g. in some species of *Acnistus*, *Athenaea*, *Brugmansia*, *Capsicum*, *Lycianthes*, and *Streptosolen*. Uniseriates, in woods with heterogeneous rays, usually numerous and composed of square to upright cells only or with some procumbent cells; low and rather few in *Acnistus*, *Brugmansia*, *Iochroma*, and *Solanum* p.p. Rays 4–13, mostly 7–9, per mm. Typically heterogeneous (Kribs's Type II A and B, and occasionally I), sometimes with more than 4 marginal rows of square or upright cells, rarely with 10 or more rows; homogeneous (Kribs's Types I and III) in *Duboisia*, *Fabiana*, *Grabowskia*, and some species of *Solanum*, e.g. *S. bicolor* Willd. and *S. wightii* Nees.; commonly composed of large cells that are all square or upright, e.g. in *Athenaea*, *Capsicum* (Fig. 227 A), *Cestrum* p.p., *Cyphomandra* p.p., *Nicotiana*, and *Solandra*, but the rays short and the cells small in the genera with homogeneous rays (Fig. 227 E and F); composed of small, but all square to upright, cells in some species of *Lycium*. The larger rays sometimes with sheath cells, e.g. in *Brugmansia*, *Capsicum*, *Datura*, and *Iochroma*. Crystals rare, but with large crystalliferous idioblasts in *Grabowskia*. The large-celled rays sometimes with conspicuous intercellular spaces. **Fibres** typically with simple or indistinctly bordered pits, more numerous on the radial than on the tangential walls, but the pits distinctly bordered in *Fabiana* and *Solandra* and equally numerous on both walls in the former; pits often very few in *Solanum*. Solereder refers to delicate septa in species of *Acnistus*, *Brachistus*, *Juanulloa*, *Salpichroa*, and *Solandra*. Walls usually rather thin but occasionally thick, e.g. in *Acnistus* p.p. and *Grabowskia*. Mean length 0·7–0·95 mm. Large open **radial channels** reported (1886) to be present in *Acnistus*, *Cestrum*, and *Datura*.

RHIZOME

The rhizome of *Jaborosa integrifolia* Lam. examined at Kew exhibited the following features. **Cork** superficial in origin. Primary **cortex** and pith very spongy, consisting of barrel-shaped cells appearing circular in transverse section. **Endodermis** distinct and provided with casparian thickenings. **Xylem** poorly developed; including small groups of infrequent, thick-walled vessels, up to about 30 μ in diameter. Crystal-sand present in the cortex and pith.

ROOT

Cork arising in the exodermis, and the presence of abundant crystal-sand reported by Holm (1046) in the thick roots of *Solanum carolinense* Linn. Cork deep-seated in origin in *Lycium vulgare* Dunal according to Weitz (2394). For root structure in species of economic importance see under 'Economic Uses', p. 973.

ANOMALOUS STRUCTURE

Interxylary phloem recorded in the root of *Atropa belladonna* Linn. (in the rhizome as well), *Browallia viscosa* H. B. et K., *Datura stramonium* Linn., *Scopolia carniolica* Jacq.

THE GENUS HETERANTHIA

The taxonomic affinities of the Brazilian genus *Heteranthia* have been investigated from the anatomical standpoint by Solereder (2164). He concluded that the genus is more closely related to the Solanaceae than the Scrophulariaceae, its resemblance to certain species of *Browallia*, *Melananthus*, and *Schwenkia* being particularly striking. The following anatomical features observed by Solereder in *Heteranthia* may be cited in support of this conclusion. The presence of a small amount of intraxylary phloem in the axis and in the bicollateral bundle of the midrib; the occurrence of bordered pits in the wood fibres; the small vessels and narrow rays of the xylem; the groups of thick-walled, white fibres with narrow lumina in the pericycle; the short, crisp tomentum, consisting of characteristic glandular hairs with nodular uniseriate stalks and heads divided into 2 cells by vertical walls; the chiefly caryophyllaceous stomata, present on both surfaces of the leaf but most numerous on the lower side, accompanied by a few stomata surrounded by 3 or 4 subsidiary cells; the arm-palisade cells in the mesophyll. Calcium oxalate occurs in *Heteranthia*, chiefly in the form of large, sometimes acicular, cluster crystals in the cortex, pith, and mesophyll. No crystal-sand observed.

TAXONOMIC NOTES

The woods include a considerable variety of structure, but the groups suggested by the wood anatomy do not appear to agree very closely with the taxonomic sub-divisions. Some of the larger genera, e.g. *Solanum*, exhibit a wider range of structure than is usual within one genus.

Duckeodendron has been placed in this family by Kuhlmann (1294), but it does not fit well. According to Record (1842), the wood resembles that of some of the Apocynaceae, e.g. *Couma*, much more closely than it does any of the Solanaceae examined by him.

ECONOMIC USES

Numerous culinary and medicinal plants are included amongst the Solanaceae. The most familiar culinary plant is the potato, which consists of the stem tubers of cultivated varieties of *Solanum tuberosum* Linn., a species originally discovered in South America and now cultivated in many parts of the world. The plant has been the object of numerous anatomical investigations. Reed (1898) found that the tuber is formed mainly from medullary parenchyma and from parenchyma between the xylem and medullary phloem. According to Artschwager (37), on the other hand, most of the tissue of the tuber is formed in the perimedullary region, the pith playing a less important part than was suggested by Reed. Artschwager's account is very complete from the developmental standpoint. It is interesting to note his conclusion that the inner phloem strands are usually limited to the perimedullary region, but sometimes occur near the centre of the stem as well. The innermost phloem strands belong to the stele proper and 'do not represent the vestigial remains of a second set of vascular bundles, as is thought by Worsdell to be the case in the Cucurbits. The individual phloem groups branch and anastomose freely, and there are connexions between the individual groups in the inner and outer phloem.' Periderm arises from the epidermis and hypodermis. A very long, detailed account of the developmental anatomy of the potato tuber has also been published by Lehmann (1344), whilst the structure of the sieve tubes in relation to translocation has been described by Crafts (497). The comparative anatomy of the stem and leaf of early and late varieties of potatoes cultivated in White Russia has been investigated by Danowitsch and Krinkin (539). In the stem, the ring of sclerenchyma in the pericycle was found to be wider, and the outer wall of the epidermal cells thicker in the late than in the early varieties. In the leaf, the stomata were more deeply sunken and the palisade tissue more columnar in the early than in the late kinds. Sheffield (2085) has described a necrosis in the primary phloem of potato plants affected with leaf-roll virus. The affected tissues can be stained with phloroglucinol and hydrochloric acid, and, when the disease is severe, the necrosis may extend to almost all parts of the plant except the stolon, whilst, at an early stage of the disease, infection may be observed before leaf rolling is apparent. The condition of the starch in potato tubers at different stages of ripening has been investigated by Jager and Jakolev (1141).

The tomato (*Lycopersicum esculentum* Mill.), also of South American origin, is widely cultivated for its edible fruits. The stem anatomy of this species, as described by Woodcock (2461), is fundamentally similar to that of other herbaceous members of the family, whilst its developmental anatomy has been fully investigated by Houghtaling (1087). The organization of root primordia in the pericycle and phloem of tomatoes after treatment with beta-napthoxyacetic acid has been described by Bausor, Reinhart, and Tice (155). The anatomy of graft hybrids between the tomato and species of *Solanum* has been studied by Mayer-Alberti (1462) and Lange (1319).

Other members of the Solanaceae with edible fruits include the Egg Plant (*Solanum melongena* Linn.), of which the structure of the young root and axis has been described by Thiel (2245); the Tree Tomato (*Cyphomandra betacea* Sendt) from Peru, now cultivated in southern Europe; the Cape Gooseberry (*Physalis peruviana* Linn.) from Tropical America, cultivated in India, South Africa, and other countries where its fruits are used for making jam; Capsicums and Chillies (*Capsicum annuum* Linn. and other species of *Capsicum*) used as a condiment and for various medicinal purposes. Fruits of Paniband (*Withania coagulans* Dun.) from India have the property of coagulating milk.

One of the most widely used members of the family is Tobacco, which is prepared chiefly from dried leaves of cultivated varieties of *Nicotiana tabacum* Linn. and other species of *Nicotiana*. The diagnostic microscopical characters for Tobacco include the simple, uniseriate hairs consisting of 2–10 cells, always pointed at the apex, swollen at the base, and very occasionally branched; the long-stalked secretory hairs with heads of 1 to several cells; the hairs with unicellular stalks and heads of up to about 20 cells; the dorsiventral lamina with 1 layer of palisade cells; the idioblasts containing crystal-sand, mostly in the spongy mesophyll. Anatomical differences between certain varieties of Tobacco have been described by Bachtadze (61). Multinucleate fibres in the primary phloem of Tobacco have been recorded by Esau (653), who has also investigated the developmental anatomy of the Tobacco plant. Avery (57, 58, 59) has also studied the seedling anatomy, ontogeny of the leaf, and the changes in anatomical structure induced by removing the tops. Wolf and Jones (2451) have attempted to correlate leaf structure and quality in tobacco, and the relationship between quality and the structure and density of the glandular hairs has been investigated by Bentley and Wolf (174). The phloem anatomy of tobacco affected with curly top and mosaic has been described by Esau (655).

From the medicinal standpoint, Belladonna (*Atropa belladonna* Linn.) is one of the most important members of the family. Indian Belladonna (*Atropa acuminata* Royle ex Lindley) is also used. The leaves and other aerial parts of the plant are employed as well as the roots. For the leaf the diagnostic histological features include the simple, uniseriate trichomes; the glandular hairs with uniseriate stalks and unicellular heads; the shorter glands with multicellular heads; the cruciferous stomata, most numerous on the lower surface; the dorsiventral mesophyll with a single palisade layer; the cells filled with crystal-sand in the spongy mesophyll; the arc of bicollateral vascular bundles in the midrib.

The root of *Atropa belladonna* is characterized by a few layers of brownish, quadrangular, cork cells; a fairly wide secondary phloem consisting of strands of sieve tubes embedded in parenchyma; secondary xylem, constituting most of the root and consisting of groups of vessels embedded in parenchymatous ground-tissue; vessels about 40–180 μ in diameter, with bordered and reticulate pits; occasional strands of interxylary phloem; medullary rays 1–5 cells wide; diarch primary xylem; simple and 2- to 3-compound starch grains, mostly in the secondary phloem, the individual components being about 3–30 μ in diameter; numerous cells filled with crystal-sand in the secondary phloem and ground-tissue of the xylem.

The root of *A. acuminata* can usually be distinguished from that of *A. belladonna* by the fact that, in the first of these species, the secondary xylem consists of 1–4 concentric zones of typical porous wood, separated from one another by mainly parenchymatous cylinders containing a little sieve tissue, the centre of the root being occupied by a solid core of typical porous wood.

Scopolia carniolica Jacq. and other species of *Scopolia* have been used as substitutes for Belladonna, but Schulz (2049) has pointed out that the alkaloid content of these substitutes is high. Wallis and Forsdike (2349) have shown that the palisade ratio (i.e. the number of palisade cells lying beneath a single cell of the upper epidermis) is 6–10 for *Atropa belladonna*, lower values occurring in various species of *Scopolia* and in *Solanum nigrum* Linn., whilst in *Datura stramonium* Linn. and *D. tatula* Linn. the palisade ratio is 4–7. Hence it follows that powdered Belladonna containing either *Scopolia* or *Solanum nigrum* as an adulterant would always give some values of less than 6. The palisade ratio for *Atropa belladonna* was found by Feinstein (682) to vary from 6·5 to 7·25. This high value enabled Belladonna to be distinguished from *Datura stramonium*, *Hyoscyamus niger*, and *Digitalis purpurea* Linn. (Family Scrophulariaceae) where the palisade ratios are lower, but not sufficiently distinct for the last 3 species to be distinguished from one another. Unger (2312) records that the admixture of the rhizome of *Sambucus ebulus* Linn. (Family Caprifoliaceae) with Belladonna roots can be detected by the absence of crystal-sand from the medullary rays in the *Sambucus*, although they occur in the cortex and pith of this species. Cells in the peripheral part of the pith of the *Sambucus* contain a dark orange-red secretion. These facts have been confirmed at Kew by direct observation. Another difference is that the xylem in *S. ebulus* is much more compact and the vessels occupy a much larger proportion of this tissue than is the case in Belladonna (see also under 'Caprifoliaceae', p. 757). The leaves and roots of *Phytolacca americana* Linn. (syn. *P. decandra* Linn.) (Family Phytolaccaceae, see p. 1091) have been used to adulterate the corresponding parts of *Atropa belladonna*.

Another important medicinal plant is Stramonium (*Datura stramonium* Linn.) of which the leaves and flowering tops as well as the seeds are used as a source of hyoscyamine. The seeds and leaves of *Datura metel* Linn. and the leaves of *D. innoxia* Miller are used for the same purpose in India. The diagnostic histological features of the dorsiventral leaf of *D. stramonium* include the short, usually 3-celled, warty and pointed, uniseriate, covering trichomes; the glandular hairs with unicellular stalks and multicellular heads; the mostly cruciferous and less frequent ranunculaceous stomata present on both surfaces, but most numerous on the lower side; the single layer of palisade cells up to about 130 μ long; the cluster crystals of calcium oxalate in the mesophyll, and the solitary crystals and coarse crystal-sand, chiefly situated around the large vascular bundles and in the petiole; the bicollateral structure of the larger vascular bundles.

Timmerman (2258) made a comparative study of the leaves of various species of *Datura* and showed how these can be identified by the following key.

A. Trichomes not very numerous and always of 2 kinds—short-stalked glandular hairs and warty covering hairs.
    1. Covering trichomes usually more than 35 μ in diameter at the base; basal cell often more than 50 μ in length.
        (*a*) No fragments coloured pink with hydrochloric acid (sp. gr. 1·16) or with a solution of chloral hydrate—*D. stramonium* Linn.
        (*b*) Some fragments coloured pink with hydrochloric acid (sp. gr. 1·16) or with a solution of chloral hydrate—*D. tatula* Linn.
    2. Covering trichomes usually less than 35 μ in diameter at the base, frequently curved. Basal cells seldom as much as 50 μ in length. Irregular crystalline masses often present.
        (*a*) No fragments coloured pink with hydrochloric acid (sp. gr. 1·16) or with a solution of chloral hydrate—*D. metel* Linn.
        (*b*) Some fragments coloured pink with hydrochloric acid (sp. gr. 1·16) or with a solution of chloral hydrate—*D. fastuosa* Linn.

B. Trichomes very numerous and usually of 3 kinds, smooth or slightly warty, long-stalked glandular hairs; short-stalked glandular hairs; warty covering hairs. Basal cell of the covering hairs frequently more than 50 μ in diameter at the base—*D. innoxia* Miller.

Timmerman (2259) has also described the comparative anatomy of the seeds of the same species and Santos (1988) the anatomy of species of *Datura* used in the Philippine Islands. The leaves of *Xanthium strumarium* Linn., *Carthamnus helenioides* Desf. (Family Compositae), and *Chenopodium hybridum* Linn. (Family Chenopodiaceae) have been substituted for those of *Stramonium*.

The leaves and flowering tops of Hyoscyamus (*Hyoscyamus niger* Linn.) possess medicinal properties resembling those of Belladonna, whilst the seeds of the same species are also used in medicine. The microscopical features of the dorsiventral leaf of *H. niger* include the numerous, 2- to 8-celled, uniseriate trichomes up to 300 μ long; the glandular hairs with long stalks and heads composed of a few cells; the relatively infrequent, short-stalked, glandular hairs with multicellular heads; the cruciferous stomata on both surfaces; the single layer of palisade cells; the numerous angular, solitary, or infrequently paired crystals, mostly in cells situated immediately below those of the palisade layer; the occasional cluster crystals and crystal-sand. Egyptian Hyoscyamus (*H. muticus* Linn.) possesses branched, glandular trichomes, but with the apices often missing.

When difficulty is encountered in identifying the roots and rootstocks of various members of the Solanaceae of interest to pharmacognoscists, the description of some of them by Lewinsky (1367) may usefully be consulted.

Duboisia myoporoides R. Br. and other species of *Duboisia* have aroused interest in Australia as a source of hyoscyamine and hyoscine. The diagnostic histological features of *D. myoporoides* include in the leaf the cruciferous stomata, usually confined to the lower surface, but seen on the upper surface as well in a herbarium specimen (No. 1001) from the Arnold Arboretum; the generally dorsiventral, but somewhat variable, mesophyll with 1 layer of palisade cells; the midrib raised above and below the general level of the lamina by collenchymatous ridges; the single, crescentic vascular strand in the midrib and petiole; the occasional cells filled with crystal-sand. The characters for the stem include the cork arising in the outer part of the cortex; the ring of thick-walled but occasionally compressed fibres with wide lumina in the pericycle; the narrow intra- and extra-xylary phloem; the continuous cylinder of xylem, including unevenly distributed vessels which are up to 60 μ in radial diameter and tend to be in radial rows in the first-formed wood, but more often in oblique or tangential rows or irregular clusters in the later wood; the simple perforations and horizontal lateral bordered pits of the vessels; the yellow deposits in some of the vessels; the occasional stone cells in the pith which is otherwise parenchymatous and composed of cells with pitted walls; the occasional intercellular cavities in the cortex; the strands of intraxylary phloem; the presence of crystal-sand. *D. leichardtii* F. Muell. is not easy to distinguish from *D. myoporoides*, but in the former the stomata are approximately half as numerous on the upper as on the lower surface, and the mesophyll tends to be isobilateral. In *D. hopwoodii* F. Muell. the stomata are only slightly less numerous on the upper than on the lower surface, whilst the ridge on the upper surface of the midrib is grooved in this but not in the other 2 species, short-stalked glandular hairs being present in the groove.

Other members of the Solanaceae which have been described by pharmacognoscists include the following. Quina de Sao Paulo, a bark with alleged antimalarial properties, derived from *Solanum pseudo-quina* St. Hil. (Brocardet 276); Miré, a stem and leaf drug from Bolivia, believed to be derived from '*Brunfelsia hydrargaeformis* Pohl.' (Youngken 2495); *Nicandra physaloides* (L.) Pers. (Hogstad 985); *Lycium vulgare* Dunal (Weitz 2394). The structure and properties of 'Manaca-root' derived from several species of *Brunfelsia* have been described in detail by Hahmann (868).

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Acnistus, Anthocercis, Anthotroche, Atropa,* Bassovia, Browallia,* Brugmansia,* Brunfelsia,* Cacabus, Capsicum,* Cestrum,* Chamaesaracha, Cyphomandra,* Datura,* Discopodium, Duboisia,* Dunalia, Dyssochroma, Fabiana,* Goetzea, Grabowskia, Henoonia, Heteranthia, Hyoscyamus,* Iochroma, Isandra, Jaborosa,* Juanulloa, Leptoglossis, Lycium,* Lycopersicum,* Mandragora, Markea, Melananthus, Metternichia, Nicandra,* Nicotiana,* Nierembergia,* Petunia,* Phrodus, Physalis,* Physochlaina,* Poecilochroma, Protoschwenkia, Salpichroa, Salpiglossis,* Saracha, Schizanthus,* Schwenkia, Sclerophylax, Scopolia,* Sessea, Solandra, Solanum,* Streptosolen,* Trianaea, Triguera, Vestia, Withania.

* Represented in the Kew slide collection.

(ii) For Wood Structure

Acnistus, (Anthocercis), Athenaea, Brachistus, Brugmansia, Capsicum, Cestrum, Cyphomandra, Datura, Duboisia, (Dunalia), Fabiana, Grabowskia, Iochroma, (Juanulloa), Lycianthes, Lycium, Nicotiana, Nothocestrum, (Salpichroa), Sessea, Solandra, Solanum, Streptosolen.

Literature

(i) *On General Anatomy*

Artschwager **37**, Avery **57-9**, Bachtadze **61**, Bartorelli **146**, Bausor, Reinhart, and Tice **155**, Bentley and Wolf **174**, Bitter **201**, Bowman **250**, Brocardet **276**, Crafts **497**, Danowitsch and Krinkin **539**, Esau **652**, **653**, **655**, Feinstein **682**, Friedel **718**, George **2521**, Hahmann **868**, Hogstad **985**, Holm **1046**, **1060**, Houghtaling **1087**, Jager and Jakolev **1141**, Kreusch **1281**, Lange **1319**, Lehmann **1344**, Lewinsky **1367**, Lubenau **1398**, Luckwill **1400**, Mayer-Alberti **1462**, Melville, R. **1491**, Melville, C. **2528**, Reed **1898**, Rowson **2534**, Sabnis **1977**, Santos **1988**, Satina and Blakeslee **1998**, Satina, Blakeslee, and Avery **1999**, Sayeedud-Din **2011**, Scala, **2020**, **2023**, Schulz **2049**, Sheffield **2085**, Small **2131**, Solereder **2164**, Thiel **2245**, Timmerman **2258–9**, Unger **2312**, Wallis and Forsdike **2349**, Weitz **2394**, Wolf and Jones **2451**, Woodcock **2461**, Youngken **2495**.

(ii) *On Wood Structure*

Brown, F. B. H. **280**, Burgerstein **310**, **312**, Cozzo **494**, Descole and O'Donell **576**, Greguss **2522**, Greiss **817**, Kuhlmann **1294**, Pfeiffer, H. **1712**, Record **1842**, **1843**, **1851**, Record and Hess **1886**, Williams **2430**.

198. SCROPHULARIACEAE

(Fig. 228 on p. 980; Fig. 229 on p. 982; Fig. 233 on p. 1000)

Summary

(i) General

A widely distributed family consisting mainly of herbs, but including a proportion of shrubs and a few trees. Some members of the family are semi-parasitic on other flowering plants, to the roots of which they are attached by haustoria. The leaf structure is very variable, the **mesophyll** being dorsiventral in some species, isobilateral in others, whilst in a third type the lamina is composed of homogeneous tissue. **Hairs** are frequently very numerous, the non-glandular kinds being mostly simple, although branched, multicellular types also occur. Variously shaped stalked glands are fairly frequent, but peltate glands confined to a few genera. The simple hairs are sometimes calcified, silicified, or even contain bodies resembling **cystoliths.** Transverse sections through the distal end of the **petiole** nearly always exhibit a single, median, arc-shaped, vascular strand or a crescent of separate bundles. Accessory bundles are frequent in the wings. The median, petiolar vascular strand in *Paulownia* is almost closed. Collenchyma is not often well developed in the **axis,** even when there are wings or other projections from the stem. Compensation for this mechanical deficiency is sometimes provided by strands of fibres in the ribs or in the sub-epidermis. The primary **cortex** is often lacunar. The fibres in the **pericycle** may be in separate strands, in a loose ring, or, in some species, almost or wholly absent. The **xylem** of the young stem is usually in the form of a closed cylinder from which typical medullary rays are commonly, but not invariably, absent, even in woody species. In other species there are radial strips of prosenchymatous elements in the xylem ring which are devoid of vessels, and serve to mark the boundaries between the adjacent bundles (see also 'Wood', p. 984). The vessels, mostly of small diameter, are provided with simple perforations. **Crystals** of calcium oxalate are mostly small and rather infrequent, but crystalline protein bodies and yellow crystals of carotin have also been recorded.

(ii) WOOD

Vessels usually very small and numerous and sometimes with a slight radial pattern, occasionally ring-porous, often with spiral thickening, intervascular pitting most typically minute and with pits to parenchyma similar; members of medium length. **Parenchyma** usually very sparse or absent, sometimes more abundant and either aliform to confluent or diffuse. **Rays** often absent; when present, 1–9 cells wide, low to high, homogeneous to markedly heterogeneous or composed entirely of square or upright cells. **Fibres** most commonly with simple pits and thin walls, but sometimes thick-walled or with bordered pits and rarely septate; occasionally with spiral thickening; of medium length to moderately short.

LEAF

Very variable; dorsiventral, isobilateral or composed of a homogeneous mass of isodiametric cells in different genera and species. **Biologically specialized types** include the scale leaves of *Tozzia* with cavities formed by the incurving of the margins and tips of the leaf, and the acicular leaves of *Hemiphragma* with strongly inrolled margins, the stomata in this genus being confined to a groove on the adaxial side of the leaf. Leaves with grooves on both surfaces but most numerous on the lower side recorded in *Euphrasia munroi* Hook. f. by Betts (189). **Hairs** (Fig. 228) often numerous and exhibiting a considerable diversity of forms. Non-glandular hairs mostly unicellular or uniseriate. The simple trichomes calcified in *Euphrasia*, or containing structures resembling cystoliths in species of *Melampyrum* and *Odontites*. Club-shaped bodies resembling **cystoliths** also stated to occur in *Craterostigma pumilum* Hochst. Trichomes and associated cells silicified in *Melasma hispidum* Benth. Branched, multicellular trichomes (Fig. 228 A–B) recorded in *Leucophyllum*, *Paulownia*, *Verbascum*. Glandular hairs with unicellular or uniseriate stalks of varying length and heads usually composed of 1–4 cells recorded in *Alonsoa*, *Antirrhinum*, *Bartsia*, *Calceolaria*, *Capraria*, *Celsia*, *Chelone*, *Collinsia*, *Cymbalaria*, *Digitalis*, *Erinus*, *Euphrasia*, *Freylinia*, *Gratiola*, *Herpestis*, *Limosella*, *Linaria*, *Lindernia*, *Maurandia*, *Mazus*, *Melampyrum*, *Mimulus*, *Nemesia*, *Odontites*, *Paederota*, *Paulownia*, *Pedicularis*, *Peliostomum*, *Pentstemon*, *Rhinanthus*, *Russelia*, *Schwalbea*, *Scoparia*, *Scrophularia*, *Torenia*, *Tozzia*, *Verbascum*, *Veronica* (Adamson 2), *Wulfenia*, *Zaluzianskya*. Peltate glands (Fig. 228 C, D) recorded by Solereder in species of *Bartsia*, *Euphrasia*, *Herpestis*, *Melampyrum*, *Pedicularis*, *Rhinanthus*, *Tozzia*.

Peltate glands in *Castilleja*, *Lamourouxia*, *Orthocarpus*, porous glands in *Pedicularis*, and **extra-floral nectaries** in *Melampyrum* recorded by Federowicz (677). **Epidermis** frequently composed of cells with sinuous anticlinal walls. Anticlinal walls, in many woody species of *Veronica* examined by Adamson (2), straight or slightly curved and sometimes very thick and pitted; lower epidermal cells in herbaceous species of *Veronica* more sinuous. Cuticle thin, often striated. **Stomata** present on both surfaces or confined to the lower side; occasionally cruciferous, but, in the mature leaf, usually ranunculaceous. Stomata raised above the epidermis in *Verbascum thapsus* Linn. according to Holm (1067). **Hydathodes,** usually situated in the teeth at the leaf margin, recorded in *Digitalis*, *Herpestis*, *Veronica*, &c. **Hypoderm** known to occur only in a few species of *Veronica*. **Petiole** (Fig. 229 A–H and J), in transverse sections through the distal end, usually exhibiting a variously shaped median arc of xylem and phloem, or a crescentic group of separate bundles in species of *Alonsoa* (Fig. 229 H), *Antirrhinum* (Fig. 229 J), *Calceolaria* (Fig. 229 C), *Digitalis*, *Halleria* (Fig. 229 A), *Linaria*, *Lophospermum*, *Mimulus* (Fig. 229 D), *Ourisia* (Fig. 229 G), *Pentstemon*, *Phygelius*, *Scrophularia* (Fig. 229 E), *Verbascum* (Fig. 229 B), *Veronica*. Median, petiolar vascular strand of *Paulownia* (Fig. 229 F) very deeply crescentic and enclosing a number of accessory bundles between the ends of the crescent. Accessory bundles, on either side of the groove in the adaxial surface of the petiole, present as

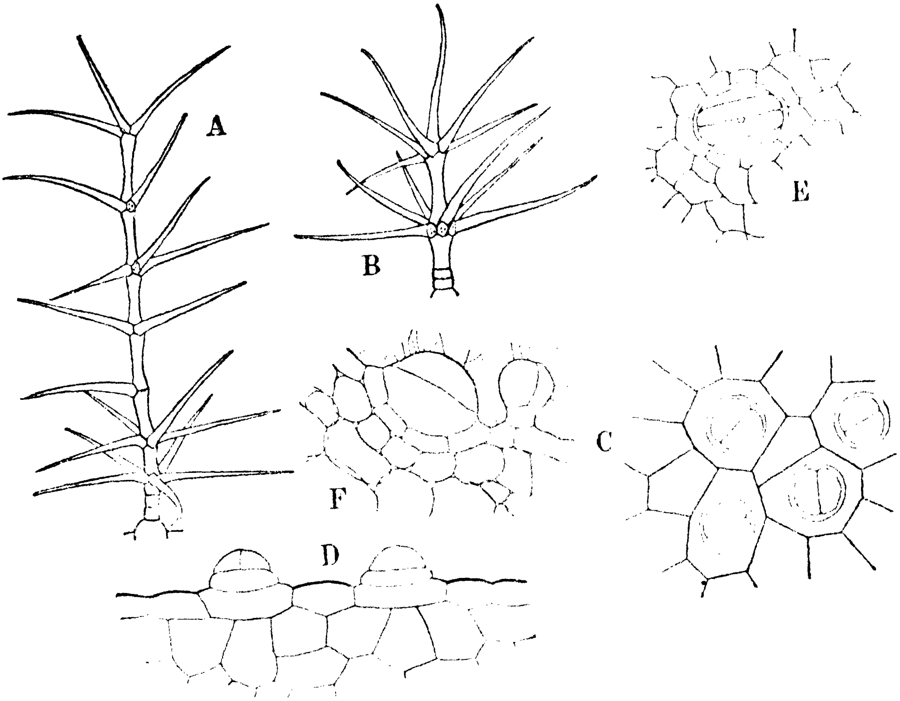


FIG. 228. *SCROPHULARIACEAE*, A–D; *OROBANCHACEAE*, E–F
A–B, Candelabra-hairs of *Verbascum thapsus* L. C–F, Peltate glands: C–D, *Pedicularis sceptrum carolinum* L., E–F, *Lathraea squamaria* L. A–D, by Solereder, E–F, after Scherffel.

well in many of the other species examined. **Crystals** rather infrequent, where present nearly always small; prismatic, octahedral or acicular in shape. Large solitary and cluster crystals recorded only in '*Calceolaria lignosa*' and *Paulownia tomentosa* Steud. Crystalline protein-bodies, associated with the nuclei of the cells of the epidermis and mesophyll, said to occur in species of *Digitalis*, *Halleria*, *Linaria*, *Lophospermum*, *Melampyrum*, *Mimulus*, *Paulownia*, *Russelia*, *Scrophularia*, *Torenia*, *Tozzia* (all organs), *Veronica*. Yellow crystals of carotin, recognizable by their solubility in alcohol and their blue colour when treated with concentrated sulphuric acid, occur in the mesophyll and near the vascular bundles of the veins in species of *Alonsoa*, *Antirrhinum*, *Celsia*, *Lophospermum*, *Scrophularia*, and other genera. The tissues are coloured red by a substance similar to carotin, in the root stem and leaf of *Craterostigma pumilum*. For pigment in the root of *Buttonia* see 'Semi-Parasitic Genera', p. 985. **Secretory elements.** Large, tanniniferous idioblasts recorded by Solereder in the mesophyll of *Scrophularia deserti* Delile.

The detailed structure of the leaf of a considerable number of shrubby species of *Veronica* has been described by Adamson (2), who has also investigated the formation of cork cells at the points of exsertion of the leaves in this genus. Interspecific differences in certain genera, based mainly on hair structure, have been described by Spoerri (2170), who divided the species he examined into 7 groups exhibiting different types of hairs.

AXIS

STEM (Fig. 229 I, K, L, M)

Cork often absent from herbaceous species; arising in the pericyclic region in at least 1 species of *Leucophyllum*; sub-epidermal in *Capraria*, *Dermatobotrys*, *Paulownia*, *Pentstemon*, and *Veronica* (Fig. 229 L). Cork consisting of a broad layer of rectangular thin-walled cells in *Dermatobotrys saundersii* Bolus. For particulars of the peculiar method of cork formation in *Veronica lyallii* Hook. f. see the description by Gray (807). Strands of sclerenchymatous fibres present in the sub-epidermal region of the **ribs** in species of *Bonnaya*, *Lindernia*, *Russelia*, *Torenia* (Fig. 229 I), *Vandelia*, and isolated fibres in the corresponding region in species of *Linaria* and *Melampyrum*. The ribs of other genera and species often consist wholly of parenchyma. Primary **cortex** including very little collenchyma even in species with wings or other projecting portions of the stem, but intercellular lacunae present in species of *Gratiola* (Fig. 229 K), *Herpestis*, *Lindernia*, *Melampyrum*, *Pedicularis*, *Rhinanthus*. Parenchymatous cells with ridge-like thickenings recorded in the lacunar tissue in *Herpestis*. Outer part of the cortex frequently chlorenchymatous. **Endodermis** often conspicuous and commonly provided with casparian thickenings in *Antirrhinum*, *Euphrasia*, *Gratiola*, *Herpestis*, *Linaria*, *Scrophularia*, and *Veronica*, but the presence or absence of an endodermis is not reliable as a diagnostic character. **Pericycle,** in most investigated species, either containing isolated strands of fibres or no sclerenchyma at all; a composite, continuous ring of sclerenchyma not previously recorded in any member of the family, but observed at Kew in *Halleria lucida* Linn. (Fig. 229 M); relatively large clusters of fibres, with stone cells between some of them, also noted in *Dermatobotrys* and *Paulownia*. Pericyclic fibres arranged in isolated strands in species of *Alonsoa*, *Antirrhinum*, *Aptosimum*, *Capraria*,

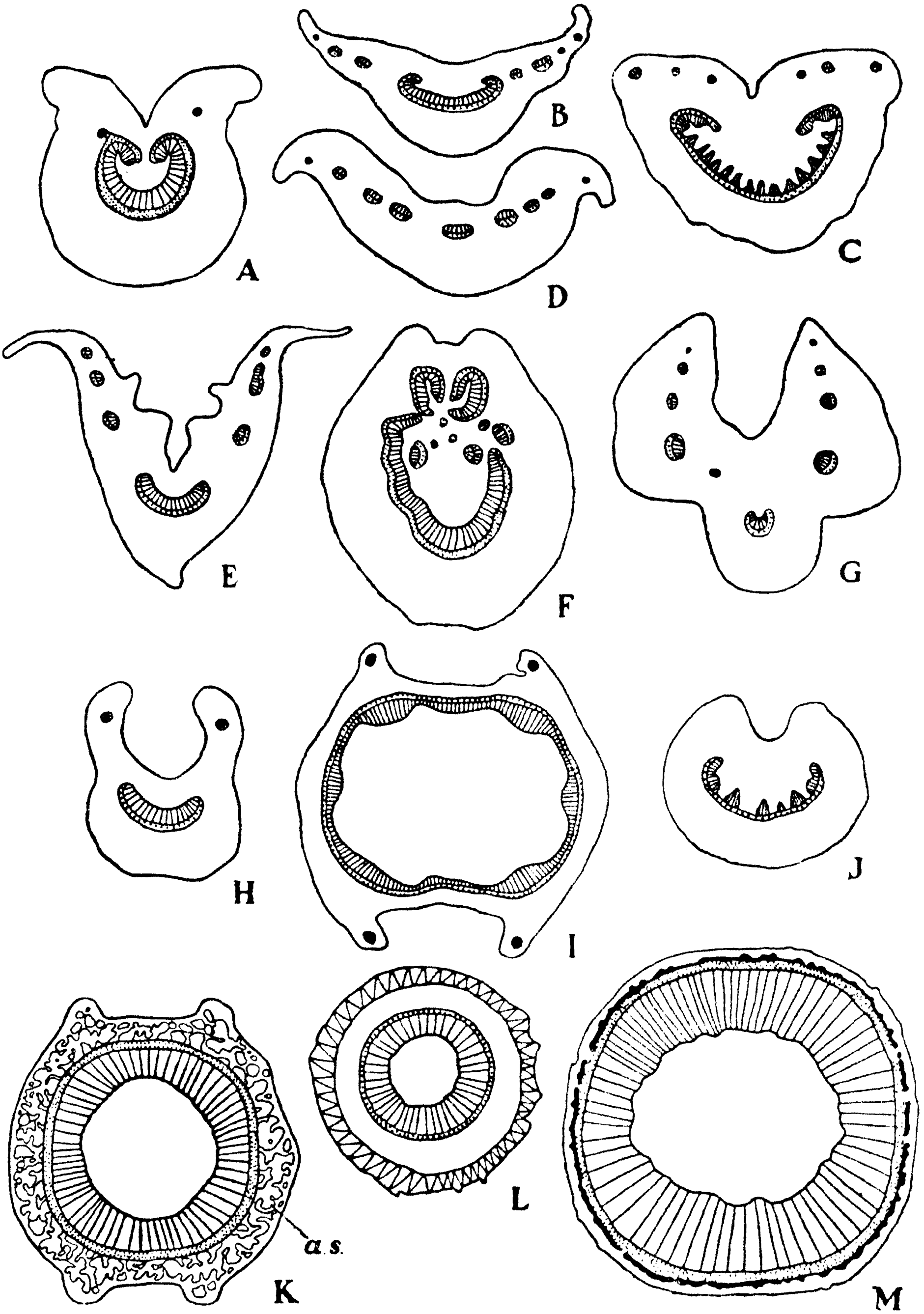


FIG. 229. *SCROPHULARIACEAE*

A, *Halleria lucida* Linn. Petiole × 26. B, *Verbascum nigrum* Linn. Petiole × 9. C, *Calceolaria mexicana* Benth. Petiole × 14. D, *Mimulus guttatus* DC. Petiole × 14. E, *Scrophularia aquatica* Linn. Petiole × 6. F, *Paulownia tomentosa* Steud. Petiole × 14. G, *Ourisia macrophylla* Hook. Petiole × 7. H, *Alonsoa myrtifolia* Roezl. Petiole × 20. I, *Torenia fournieri* Linden. Stem × 17. J, *Antirrhinum asarina* Linn. Petiole × 20. K, *Gratiola officinalis* Linn. Stem × 17. L, *Veronica fruticans* Jacq. Stem × 19. M, *Halleria lucida* Linn. Stem × 8.

a.s. Assimilatory tissue with numerous lacunae.

Dermatobotrys, *Gratiola*, *Halleria*, *Leucophyllum*, *Linaria*, *Nemesia*, *Nycterinia*, *Pentstemon*, *Schweinfurthia*, *Scrophularia*, *Verbascum*, *Veronica*; in bands in species of *Chelone* and *Linaria*; absent from or very rare in species of *Collinsia*, *Euphrasia*, *Herpestis*, *Mimulus*, *Pedicularis*, *Rhinanthus*; forming a loose or dense ring in species of *Bartsia*, *Celsia*, *Digitalis*, *Gerardia*, *Paederota*. Extensions of the fibres from the pericycle to the xylem cause the phloem, in the last group of genera, to appear as islands in transverse sections. **Xylem** in young stems nearly always in the form of a closed cylinder, but showing a considerable range of structure when viewed in transverse section, owing to variations in the size and distribution of the vessels and also in the proportion of the stem occupied by the wood in different genera and species. Vessel arrangement sometimes varying considerably within a genus, e.g. in *Scrophularia aquatica* Linn. and *S. nodosa* Linn. Classification of the stems of species represented in the Kew slide collection from the nature of the xylem proved difficult owing to the lack of well-defined categories, but the following particulars give some indication of the range of structure.

(i) Vessels mostly solitary but tending to be in interrupted radial rows; evenly distributed throughout the xylem; members seldom more than 10 μ in radial diameter—*Veronica fruticans* Jacq., *V. traversii* Hook. f.

(i *a*) Similar to (i), but vessels in more definite radial rows and up to about 20 μ in radial diameter—*Veronica incana* Linn., *V. longifolia* Linn., *V. spicata* Linn.

(i *b*) Similar to (i), but vessels up to 50 μ in radial diameter, and definite medullary rays present—*Halleria lucida* Linn.

(ii) Vessels of primary wood in radial rows; those of the secondary xylem mostly solitary, but a few in radial, tangential, and oblique clusters, evenly distributed throughout the ground-tissue and seldom exceeding 30 μ in radial diameter—*Pentstemon diffusus* Dougl., *Scrophularia nodosa* Linn. (slight tendency towards type (ix) in this species), *Verbascum nigrum* Linn.

(iii) Vessels solitary and in short radial rows, fairly evenly distributed throughout the wood, mostly less than 20 μ in radial diameter—*Diascia barbarae* Hook. f.

(iv) Vessels mostly solitary but some in short radial groups, rather angular, about 30 μ in radial diameter—*Mimulus luteus* Linn.

(v) Vessels up to 30 μ in radial diameter, and arranged in radial rows—*Alonsoa myrtifolia* Roezl., *Torenia fournieri* Linden.

(vi) Vessels in radial rows, but not clearly differentiated from the surrounding ground-tissue, owing to the vessel members being mostly about 15 μ in diameter, and, therefore, not very different in appearance from the wood fibres—*Euphrasia officinalis* Agg.

(vii) Vessels very numerous and crowded, in radial rows, mostly less than 40 μ in radial diameter—*Digitalis purpurea* Linn., *Gratiola officinalis* Linn., and the primary wood of *Paulownia tomentosa* Steud.

(viii) Vessels unevenly distributed, in radial rows only in the primary wood, elsewhere solitary or in tangential groups or pairs, up to about 70 μ in radial diameter—*Antirrhinum asarina* Linn. Similar but with the xylem reduced and vessels up to about 36 μ in radial diameter in *Linaria cymbalaria* (L.) Mill.

(ix) Vessels in radial rows, but confined to certain segments of the xylem, the tissue in the intervening areas, probably homologous with the medullary rays, composed wholly of prosenchymatous elements. Vessels up to about 36 μ in radial diameter—*Antirrhinum majus* Linn., *A. orontium* Linn., *Zaluzianskya capensis* Walp. Similar structure previously recorded by Solereder in species of *Antirrhinum*, *Mazus*, *Vandelia*, and in *Herpestis* by Sayeedud-Din (2004).

(x) Similar to (ix), but xylem cylinder narrower and vessels most numerous in the primary xylem and rather larger in diameter—*Calceolaria mexicana* Benth. Also similar, but with less numerous primary xylem groups, in *Nemesia floribunda* Lehm. and *N. pubescens* Benth.

(xi) Xylem not well developed, probably a reduced form of type (x)—*Ourisia macrophylla* Hook.

Another noteworthy feature of the xylem is the absence of typical medullary rays from herbaceous and from many woody species. Typical rays observed at Kew only in *Halleria lucida*, but recorded in a few other genera and species, e.g. uniseriate rays in *Euphrasia munroi* Hook. f. by Betts (189), conspicuous rays in *Verbascum thapsus* Linn. by Holm (1067), and numerous uniseriate rays in *Anticharis linearis* Hochst. by Sabnis (1977) (see also 'Wood', p. 985). Vessel perforations always simple. **Pith** at first septate and then fistular in *Paulownia tomentosa*; containing stone cells in species of *Capraria* and *Dermatobotrys*. **Secretory elements.** None seen in the species examined at Kew, apart from cavities in the sub-epidermal region of the cortex of *Scrophularia aquatica* Linn.

Wood (Fig. 233 A–I)

Vessels typically small (less than 100 μ mean tangential diameter) and sometimes extremely small (less than 25 μ), e.g. in some species of *Anastrabe*, *Calceolaria*, *Monttea*, *Pentstemon*, and *Veronica*, medium-sized (100–200 μ) in some species of *Dermatocalyx* and *Scoparia*, and large (about 230 μ) in *Wightia gigantea* Wall.; solitary and in multiples of 2 or 3 cells, with a tendency to radial rows in *Anastrabe*, *Diplacus*, *Halleria*, and *Veronica*; 2–260 per sq. mm., 7 or fewer in the species with medium-sized to large vessels, 100 or more in those with extremely small vessels; ring-porous in *Paulownia* and *Pentstemon* and tending to be ring-porous in *Dermatocalyx*; spiral thickening has been noted by Solereder in *Aptosimum*, *Castileja*, *Freylinia*, *Leucophyllum*, *Lyperia*, and *Veronica*, and to these genera may be added *Gerardia* (1851), *Monttea*, and *Pentstemon*. Perforations simple. Intervascular pitting usually very small to minute, but larger in *Paulownia*, *Pentstemon* p.p., *Scoparia*, and *Wightia*; pits to parenchyma similar to the intervascular pitting except in *Scoparia* and *Wightia*, in which some larger, elongated pits occur. Tyloses observed only in *Paulownia*. Vessel member length 0·25–0·35 mm. **Parenchyma** usually very sparse or absent; with narrow sheaths round the vessels in the only available specimen of *Dermatocalyx parviflorus* Oerst.;[1] abundant, and aliform to confluent in *Paulownia* (Fig. 233 H); predominantly apotracheal, as numerous short uniseriate lines in

---

[1] Record and Hess (1886), however, describe the parenchyma in this species as 'in fine irregularly spaced bands'.

Scoparia and *Wightia*, with some paratracheal in the latter. Strands of 1–2 cells in *Paulownia* and of 2–4 cells in the other genera. **Rays** absent from at least some species of *Alonsoa* (2158), *Calceolaria*, *Castilleja*, *Pentstemon*, and *Veronica* (Fig. 233 G); mostly up to 3–5 cells wide in the other genera, wholly uniseriate in *Scoparia* and up to 9 cells wide in *Antirrhinum junceum* A. Gray; usually distinctly less than 1 mm. high, but considerably higher in *Antirrhinum* and *Halleria*; uniseriate rays low in *Anastrabe* and *Wightia* and very few in *Antirrhinum*, *Paulownia*, and *Pentstemon* p.p.; and composed of mixed procumbent and square to upright cells in these genera, except *Paulownia* (all procumbent) and in *Dermatocalyx*; composed of square to upright cells in the other genera; 1·5–16 rays per mm., fewer than 5 per mm. in some species of *Antirrhinum*, *Paulownia*, and *Wightia*, most numerous, 10 or more per mm., in species of *Diplacus*, *Halleria*, *Monttea*, and *Scoparia*; varying from homogeneous (Kribs's Type II), e.g. in *Paulownia*, to markedly heterogeneous (Kribs's Types I–II A) with several rows of square or upright cells, e.g. in *Halleria*; composed entirely of square or upright cells in *Antirrhinum*, *Diplacus*, *Pentstemon*, and *Scoparia*. Very small crystals of various shapes present in *Dermatocalyx* and *Monttea* (1886). **Fibres** thick-walled and septate in *Anastrabe* and *Halleria* and occasionally septate in *Dermatocalyx*; pits with moderately distinct borders in *Monttea* and, according to Solereder, in *Freylinia*, and with small borders in *Dermatocalyx*, *Pentstemon* (1886), and *Veronica*; with spiral thickening in *Dermatocalyx* (1886) and *Monttea*. Mean fibre length 0·8–1·2 mm.

ROOT

Superficial cork recorded in *Sophronanthe* by Holm (1009). Long secondary roots with tetrarch structure also observed by Holm (1008) in *Chelone glabra* Linn.

SEMI-PARASITIC GENERA

Euphrasia, *Melampyrum*, and *Rhinanthus* are amongst the genera which are partly parasitic on the roots of other flowering plants. Boeshore (215) regards these semi-parasites as forming a continuous series with the Orobanchaceae which are much more completely heterotrophic. The structure and development of the haustoria of *Striga lutea* Lour., which is parasitic on native grasses and on *Zea mays* Linn. in various parts of South and East Africa, have been investigated by Stephens (2195, 2196). The haustoria arise exogenously from the hypodermal or sub-hypodermal layer. They first appear as papillae which penetrate the host by secreting an enzyme. Tracheids formed in the centre of the haustorium serve to connect the vessels of host and parasite. The haustorium becomes globular in outline, following cell divisions in the parenchyma around the axial strand of tracheids. The structure of the aerial stem of *S. lutea*, like that of many other members of the Scrophulariaceae, shows a closed ring of xylem, vessels with small lumina, whilst typical medullary rays are lacking.

Boodle (233) has described the root and haustorium of *Buttonia natalensis* Macken., a handsome climbing plant from Natal, which is partly parasitic on a Euphorbia. The haustoria of *Buttonia* are not unlike those of *Striga*. *Buttonia* is also of interest because of a yellow, orange, or brown pigment, believed to belong to the xanthic series, which is present in the root either as a granular mass in the phloem cells, or as granules in the cortex. The pigment in the cortex is concentrated chiefly in special thickenings of the cell wall, the stratified structure of which can be made apparent by dissolving the pigment in alcohol. Microchemical tests indicate that the thickenings consist of a somewhat resistant substance, related to mucilage, but containing a small admixture of protein.

Julg (1203), who examined the haustoria of *Alectorolophus* and *Melampyrum*, failed to find any evidence that the haustoria are analogous to, or have the same function as, the bacterial nodules of the Leguminosae.

TAXONOMIC NOTES

The stem anatomy of the Scrophulariaceae is not unlike that of the Solanaceae except that intraxylary phloem is absent from the former. It is noteworthy that *Heteranthia*, which by some authorities is included in the Scrophulariaceae, has, in this book, been described under Solanaceae as recommended by Solereder (2164). For further details see p. 972. Solereder (2159) has also discussed the taxonomic position of *Rehmannia* from the anatomical standpoint, but his investigations were confined mainly to the floral organs. Holm (1009) has claimed, on anatomical grounds, that *Sophronanthe* should be treated as a distinct genus from *Gratiola*. Boeshore (215) has shown how the Orobanchaceae may be regarded as 'reduced' from plants similar to members of the Scrophulariaceae in response to an increasingly heterotrophic mode of life.

The wood anatomy is far from homogeneous, *Scoparia*, *Wightia*, and possibly *Paulownia*, being exceptional.

ECONOMIC USES

Various medicinal products are obtained from the Scrophulariaceae. Of these, one of the most important is the dried leaves of the Foxglove (*Digitalis purpurea* Linn.), the glycosides in which are used as heart stimulants. The diagnostic histological characters of the dorsiventral leaf include the abundant, uniseriate, slightly warty covering trichomes, each consisting of 3–5 cells; the less frequent glandular hairs with 1- or 2-celled heads on short, generally unicellular, but occasionally uniseriate stalks; the cells of the upper epidermis with sinuous or occasionally straight anticlinal walls; the more sinuous anticlinal walls of the lower epidermal cells; the ranunculaceous stomata, more numerous on the lower than on the upper surface; the 1 or 2 hydathodes at the apices of most of the teeth; the absence of sclerenchyma and of calcium oxalate crystals; the vein-islet number of 2·0–5·5. The potency of samples collected in different parts of the British Isles has been investigated by Watson and James (2369).

The leaves of other species of *Digitalis* are also used, and are sometimes confused with those of *D. purpurea*. The diagnostic characters of the alternative species have been the subject of several investigations by Dewar (578, 579), Dewar and Wallis (580), Jacobs (1135), Konnerth and Pickering (1266), Kraemer (1274), Levin (1366), and Youngken (2492). *D. lanata* Ehrhard differs from *D. purpurea* in the following respects: vein-islet number 2–8; non-glandular trichomes infrequent, 10- to 14-celled; anticlinal walls of the cells of the upper and lower epidermis beaded. For *D. lutea* Linn. the microscopical features include the vein-islet number of 1–2; the infrequent, non-glandular, uniseriate, 4- to 6-celled trichomes; the thickened apices of the angles in the sinuous anticlinal walls of the epidermal cells; the occasional presence of fibres. The characters for *D. thapsi* Linn. are the vein-islet number of 8·5–16; the absence of non-glandular trichomes; the numerous glandular hairs with 3- to 4-celled, uniseriate stalks and unicellular or bicellular heads; the straight or slightly sinuous anticlinal walls of the epidermal cells; the presence of fibres; the small prismatic crystals of calcium oxalate scattered throughout the mesophyll; the generally solitary hydathodes on each leaf-tooth. The histology of *D. ambigua* Murr. has been described by Jacobs (1135) and that of *D. sibirica* Lindl. by Youngken (2492). Differences in the striation and wartiness of the cuticle on the hairs and epidermal cells in species of *Digitalis* have been used for diagnostic purposes, but these characters seem to be somewhat variable judging from the very detailed work on this subject by Oehm (1633). The woolly leaves of *Verbascum thapsus* Linn. can be detected in samples of *Digitalis* leaf by the branched, candelabra-hairs, and those of *Symphytum officinale* Linn. by isolated, stiff hairs.

The dried rhizome of *Picrorrhiza kurroa* Royle from the Himalayas is used in the preparation of a tonic and for other medicinal purposes. The greyish-brown rhizomes occur in the form of pieces about 2·5–5 cm. long and 4–8 mm. thick. The microscopical features include the tangentially elongated, thin-walled cork cells with wide lumina; the somewhat spongy parenchyma of the cortex and pith; the xylem which includes numerous, evenly distributed vessels mostly 15–30 μ in diameter, the component members being usually less than 45 μ long, but occasionally attaining a length of 130 μ; the horizontally elongated pits and somewhat oblique perforations of the vessels.

Leptandra or Culver's Root, also used in medicine, consists of the dried rhizome and roots of *Veronica virginiana* Linn. which occurs in North America. The woody rhizome occurs in pieces 5 cm. long and 1 cm. in diameter. The microscopical features include the narrow layer of cork, composed of thin-walled cells; the parenchymatous cortex; the pericycle containing a slightly interrupted ring of thick-walled, pitted fibres and stone cells; the absence of sclerenchymatous elements from the broad phloem; the absence of true medullary rays from the cylindrical xylem; the scattered vessels up to about 40 μ in diameter provided with oval bordered pits or horizontally elongated pits with less conspicuous borders, and very oblique, simple perforations; the spongy, parenchymatous pith; the abundant starch in the cortex and pith, the individual grains nearly spherical or polygonal and generally less than 9 μ in diameter; the occasional yellow or orange contents in some of the parenchymatous cells.

Euphrasia officinalis Linn., *Veronica officinalis* Linn., and *Scrophularia nodosa* Linn. were at one time used in medicine, but are not now of any great importance. Species of *Calceolaria*, *Digitalis*, *Paulownia*, *Pentstemon*, *Verbascum*, and *Veronica*, &c., are common ornamental plants.

GENERA DESCRIBED

(i) GENERAL ANATOMY

Alectorolophus, Alonsoa,* Anticharis, Antirrhinum, *Aptosimum, Bartsia, Bonnaya, Buttonia, Calceolaria,* Capraria, Castilleja, Celsia, Chelone, Collinsia, Craterostigma, Cymbalaria, Dermatobotrys,* Diascia,* Digitalis,* Erinus, Euphrasia,* Freylinia, Gratiola,* Halleria, Hemiphragma, Herpestis, Lamourouxia, Leucophyllum, Limosella, Linaria,* Lindernia, Lophospermum, Maurandia, Mazus, Melampyrum, Melasma, Mimulus,* Nemesia,* Odontites, Orthocarpus, Ourisia,* Paederota, Paulownia,* Pedicularis, Pentstemon,* Phygelius, Picrorrhiza,* Rehmannia, Rhinanthus, Russelia, Schwalbea, Schweinfurthia, Scoparia, Scrophularia,* Sophronanthe, Striga, Torenia,* Tozzia, Vandellia, Verbascum,* Veronica,* Wulfenia, Zaluzianskya.*

* Represented in the Kew slide collection.

(ii) WOOD STRUCTURE

(Alonsoa), Anastrabe, Antirrhinum, (Aptosimum), Calceolaria, Castilleja, Dermatocalyx, Diplacus, (Freylinia), (Gerardia), Halleria, Leucophyllum, Lyperia, Monttea, Paulownia, Pentstemon, Scoparia, Veronica, Wightia.

LITERATURE

(i) *On General Anatomy*

Adamson **2**, Betts **189**, Boeshore **215**, Boodle **233**, Dewar **578**, **579**, Dewar and Wallis **580**, Federowicz **677**, Gray **807**, Greenish and Wallis **811–12**, Holm **1005**, **1008**, **1009**, **1011**, **1013**, **1059**, **1067**, Jacobs **1135**, Julg **1203**, Konnerth and Pickering **1266**, Kraemer **1274**, Kränzlin **1276**, Levin **1366**, Matthiesen **1458**, Nyrac **1623**, Oehm **1633**, Rowson **2534**, Sabnis **1977**, Sayeedud-Din **2004**, Small **2131**, Solereder **2159**, **2164**, Spoerri **2170**, Stephens **2195**, **2196**, Watson and James **2369**, Youngken **2492**.

(ii) *On Wood Structure*

Greguss **2522**, Howard **1088**, Janssonius **1154**, Kanehira **1206**, **1209**, **1214**, Nicoloff **1593**, Record **1783**, **1843**, **1851**, Record and Hess **1886**, Tang **2231**, Yamabayashi **2478**.

199. OROBANCHACEAE

(FIG. 228 on p. 980; FIG. 235 on p. 1006)

SUMMARY

A rather irregularly distributed family of parasitic herbs that derive their nourishment from the roots of host plants, usually via haustoria which arise laterally from the roots. Tubers occur in *Aeginetia indica* Linn. and *Christisonia subacaulis* Gardn. from which the lateral roots and stems are produced. The host plants are all angiosperms belonging to widely different families of the Monocotyledons and Dicotyledons. Some species are confined to specific host plants, but others do not exhibit the same degree of specialization. Chlorophyll is usually completely absent, and the leaves are reduced to scales.

LEAF

Reduced to scales. More or less numerous glandular **hairs** (Fig. 228 E–F), with stalks composed of 2 to several cells present on all members of the family. Stalks of the hairs usually simple, but sometimes branched and generally composed of slightly thickened cells; cell walls occasionally thicker and provided with pores, e.g. in *Kopsiopsis* and *Orobanche pinorum* Geyer, according to Beck-Mannagetta (165). Glandular heads becoming divided by vertical and periclinal walls, an oily secretion accumulating between the outer wall and the uplifted cuticle. Peltate glands recorded in *Christisonia*. Simple, non-glandular hairs also occur, especially on the floral organs. **Stomata** occur in the leaf of all investigated members of the family, and frequently in the stem as well, but sometimes become disorganized. **Hydathodes** occur in hollow cavities in the leaf of *Lathraea* (see 'Biology and Taxonomic Position', p. 990). A **hypoderm** of several layers of thickened lignified cells recorded by Beck-Mannagetta (165) only in *Conopholis*. **Mesophyll** composed of a dense homogeneous mass of spherical cells. Isolated, sclerenchymatous idioblasts recorded in the mesophyll of *Kopsiopsis*.

AXIS

STEM

Ground-tissue of the **cortex** and **pith** composed of large-celled parenchyma in *Orobanche hederae* Duby and other species, but lignified in some members of the family. **Vascular bundles,** according to Beck-Mannagetta (165), usually form a single ring as seen in transverse sections, but are less frequently arranged in 2 or more circles; the inner bundles being described as 'medullary' by some authors. Vascular bundles generally separated from one another by conspicuous medullary rays.

The following facts were noted at Kew concerning the vascular system in the aerial stem of *Lathraea squamaria* Linn. (Fig. 235 F) and *Orobanche hederae* (Fig. 235 D). Phloem more fully developed than the xylem in both species; appearing, in transverse sections, as an almost continuous ring in *L. squamaria*, and as more widely spaced strands in *O. hederae*. Xylem less continuous than the phloem in *L. squamaria*; in the form of separate strands in *O. hederae*, separated from one another and accompanied towards the pith by a continuous ring of somewhat prosenchymatous cells with moderately thick-walled, pitted cells. A ring of prosenchymatous elements with wide lumina and only slightly thickened walls surrounds the outside of the phloem in *L. squamaria*, but no prosenchymatous elements observed in the corresponding position in *O. hederae*. Mechanical support is thus provided externally to the vascular system in *L. squamaria* and on the inside of the vascular system in *O. hederae*.

Species, but not genera, said by Beck-Mannagetta to be distinguishable by differences in the thickening of the vessel members and in the nature of the ground-tissue of the xylem. Course of the vascular strands very irregular in the swollen stem bases of *Orobanche hederae* according to Tate (2236). Vessel perforations simple; with spiral thickening and reticulate pitting in *Orobanche hederae*. Compound **starch grains** usually abundant in the ground-tissue.

ROOT

Primary structure usually diarch, or, less frequently, triarch or tetrarch in *Lathraea* according to Chemin (390). **Root hairs** absent from at least *Aeginetia indica* Linn. (Juliano 1204), *Christisonia* (Worsdell 2467), and *Lathraea* (Chemin 390). **Cork** not formed in *Lathraea* but replaced by a thin, cuticular layer. Roots short, and composed of large amyliferous cells surrounding the central vascular bundle in *Orobanche hederae* Duby, according to Tate (2236); those of *Aeginetia indica* described by Juliano (1204) as resembling rhizomes in structure, but with the xylem reduced and the phloem enlarged, and lacking root hairs and root caps. According to Juliano the structure of the roots is not such as to exclude the possibility of water being absorbed by them directly from the soil.

BIOLOGY AND TAXONOMIC POSITION

All who have investigated the morphology and anatomy of the Orobanchaceae agree that members of the family show various degrees of reduction in relation to their parasitic mode of life. Nourishment is generally derived from the host by haustoria, which, at least in *Christisonia* according to Worsdell (2467) and in *Lathraea* according to Chemin (390), arise exogenously from the roots which are devoid of absorbing hairs. Chemin found in *Lathraea* that the haustoria penetrate the roots of the host by a digestive action which may persist for a time even when the parasite has become firmly established. The haustoria may remain alive for several years, but become detached sooner or later. According to Tate (2236) there are no definite haustoria in *Orobanche hederae* Duby, the union between the parasite and its host the ivy (*Hedera helix* Linn.) extending over a considerable area. The ivy itself plays an important role in effecting a union, whilst the xylem, phloem, and cortical cells of the 2 organisms come into intimate contact. Returning to Chemin's work on *Lathraea*, it may be noted that the host reacts to invasion by forming tyloses in the vessels and cork in the cortex. The mode of formation of the haustoria and their penetration of the host tissue resemble those processes described for the less completely parasitic members of the Scrophulariaceae such as *Striga* and *Buttonia* (see Scrophulariaceae, p. 985). This similarity supports the opinion of Boeshore (215) that the Orobanchaceae are related to the Scrophulariaceae, and that members of the 2 families may be arranged in a continuous series showing increasing dependence on heterotrophic nutrition. According to Chemin the scale leaves of *Lathraea* are of considerable importance in the life of the plant, since they serve as secretory structures through which is eliminated the water taken up from the host together with sulphates and phosphates of ammonia formed by the metabolism of the parasite. The surrounding plants derive benefit from these secretions. The scale leaves serve also for the storage of starch. Cavities, with communications to the exterior, occur in the scale leaves of *Lathraea*. The presence in these hollow spaces of animal organisms and their remains, together with the occurrence of shortly stalked, capitate and peltate glands on the epidermis which lines them, has given rise to the idea that the plants are insectivorous. Scherffel (2030) has shown, however, that the cavities possess no suitable apparatus for the capture of animal organisms, whilst the epidermal glands are not connected with the vascular system. These facts indicate that the glands in the cavities serve only as hydathodes. It is noteworthy that both lateral roots and stems arise endogenously in *Christisonia* according to Worsdell (2467) and in *Aeginetia indica* Linn. according to Juliano (1204). Juliano has also pointed out that in *Aeginetia*, owing to the lack of cuticular protection and other structural features which prevent loss of water, the plant can flourish only in the shade. A comparatively recent taxonomic monograph of the family is the one published by Beck-Mannagetta (165).

ECONOMIC IMPORTANCE

Members of the family yield no products of economic importance, but many of them are parasitic on important crop plants, e.g. species of *Orobanche* on hemp, tobacco, cotton and leguminous fodder plants. *Aeginetia indica* Linn. occurs on *Saccharum* and other tropical grasses. Its structure and life-history in relation to sugar-cane crops in the Philippine Islands has been fully described by Juliano (1204).

GENERA DESCRIBED

It is difficult to indicate exactly which genera have been examined anatomically, owing to the fact that many of the plants mentioned in the older literature have since been reclassified. The genera actually mentioned in the above account are as follows:

Aeginetia,* Christisonia, Conopholis, Kopsiopsis, Lathraea,* Orobanche.*

*Represented in the Kew slide collection.

LITERATURE

On General Anatomy

Arnaudow **36**, Beck-Mannagetta **165**, Boeshore **215**, Chemin **390**, Juliano **1204**, Scherffel **2030**, Tate **2236**, Worsdell **2467**.

200. LENTIBULARIACEAE

(FIG. 230 on p. 992; FIG. 231 on p. 992)

SUMMARY

A temperate and tropical family of herbs which grow in marshy habitats or immersed in water. They are chiefly remarkable for specializations in the leaf morphology by which insects and other minute animal organisms are ensnared and digested. These leaf specializations take very different forms in the various genera, for which reason they are described separately below. A complete account of the structure and biology of these plants has been published by Lloyd (1383) whose book includes a comprehensive bibliography.

1. PINGUICULA

Plants provided with true roots, and possessing a basal rosette of simple leaves with incurved margins, the surface of the lamina being covered with glandular hairs. The genus occurs in temperate regions of the northern hemisphere.

LEAF

Mesophyll composed of more or less isodiametric cells. Sessile glandular **hairs** present on both surfaces of the leaf; but stalked types confined to the upper side. Stalked glands (Fig. 230 A–C) each have a basal cell, a few stalk cells, and a disk-shaped, multicellular, secretory cap, the latter composed of radially arranged cells with sieve-like perforations to the cuticle. The apical cell of the stalk penetrates the cap in rather the same way as the columella grows into a sporangium of *Mucor*. Sessile glands are somewhat depressed below the leaf surface, but otherwise similar to those just described, apart from the absence of the stalk. All glands on the upper surface in *P. vulgaris* Linn. said to be directly connected to the vascular system by means of vessels. Thin-walled, uniseriate hairs occur amongst the stalked glands in *P. vulgaris*. Some of the cells of the glands and of the epidermis contain crystalloids. **Stomata** present on both surfaces in *P. vulgaris* and *P. alpina* Linn. except near the margins, where they are absent from the upper side; mostly caryophyllaceous.

AXIS

SCAPE

Vascular bundles arranged in a ring.

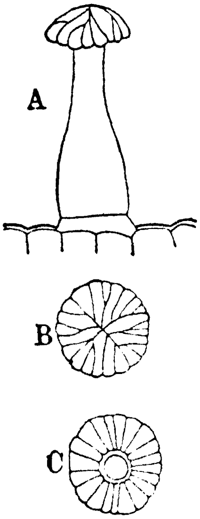


FIG. 230. *LENTIBULARIACEAE*

External glands of *Pinguicula alpina* L.; in B and C the gland is separated from the stalk, and is seen from above in B, from below in C.—After J. Klein.

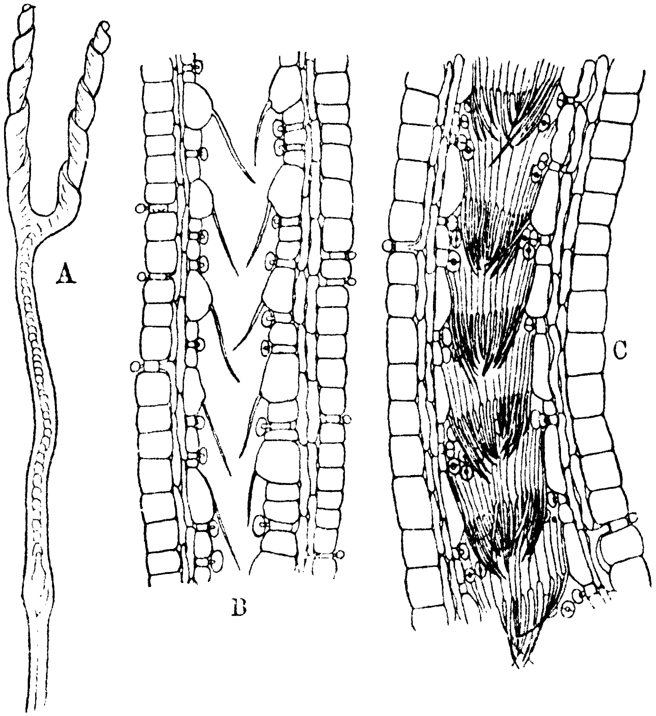


FIG. 231. *LENTIBULARIACEAE*

Genlisea ornata Mart. A, General appearance of a tubular leaf; B, Longitudinal section from the neck-portion; C, Longitudinal section through one arm.—After Goebel.

2. GENLISEA

A genus of rootless plants with basal rosettes of numerous simple leaves, together with complex, tubular (ascidiform) leaves directly attached to the rhizome or rootstock. Most of the species occur in Brazil and other South American countries, but at least one is native of west tropical Africa. According to Lloyd (1383) most of the species occur in swampy places, where they are usually immersed in shallow water. Hutchinson and Dalziel (1116) describe the West African species as occurring in wet grassland.

LEAF

(i) FOLIAGE LEAF

Covered with a layer of mucilage, secreted by short-stalked glands with spherical heads. **Stomata** absent.

(ii) ASCIDIFORM LEAVES

Ascidiform leaves (Fig. 231) each have a solid basal portion, supplied by a weakly developed vascular bundle; a middle part composed of a bladder-like swelling at the lower end, and a long neck above; 2 spirally twisted arms at the apex of the tube. A few small openings into the tube occur at the base of the arms. The tubular part of the leaf is supplied by 2 branches of the basal vascular bundle, each of the 2 twisted arms at the apex also being provided with 2 bundles connected to those in the middle part of the leaf. The structure of the upper end of the tubular part of the leaf (Fig. 231 B) resembles that of an eel-trap, one of the most prominent features being a series of circular zones of downwardly directed, pointed **hairs**, arranged like a sequence of funnels one above the other. Short, mucilage **glands** occur between consecutive zones of the pointed hairs. **Stomata** also present in this region. Pointed hairs absent from the lower part of the tube, but secretory glands more numerous in this region. Structure of the arms (Fig. 231 C) similar to that of the upper part of the tube, but the downwardly directed hairs not arranged in annular zones. For the mode of development of the ascidiform leaves see Lloyd's (1383) account.

AXIS

STEM

Typical **vascular bundles** absent, their place being taken by a network of phloem strands, separated by parenchyma from an independent ring of xylem enclosing a pith. Strands of xylem and phloem pass out independently to the leaf, and there become united into a definite leaf-trace bundle. Scape somewhat similar in structure, but supported mechanically by a cylinder of lignified elements; the xylem and phloem systems less sharply separated in this region.

3. UTRICULARIA

A rootless genus with a world-wide distribution and including aquatic and terrestrial species. Leaf and shoot cannot be easily distinguished. The most characteristic feature of the vegetative organs is the well-known, small, trap-like bladders.

LEAF

(i) FOLIAGE LEAF

Surface covered with small, capitate **glands.** Cylindrical portions of the leaves of *U. cornuta* Michx. consisting of a lacunar tissue of elongated parenchymatous cells surrounding an axile vascular bundle. **Mesophyll** of the aerial leaves of *U. montana* Jacq. more or less homogeneous, apart from large intercellular spaces towards the lower surface. Mesophyll of the aquatic leaves of *U. vulgaris* Linn. also homogeneous, and composed of isodiametric cells surrounding an axile vascular strand. **Stomata** present near the margin in *U. cornuta*, and on the lower surface in *U. montana*; ranunculaceous in the last species. Small, spindle-shaped **crystals** recorded in the upper epidermis of *U. montana.*

(ii) BLADDERS

The bladders or traps are of several distinct but related types, whilst those of individual species show minor variations in structure. Since the morphology and mechanism of the various kinds have been very fully described and discussed by Lloyd (1383), it would be superfluous here to do more than record a few notes about them. The traps are more or less distinctly stalked, spherical or ovoid structures each having a lateral opening. The entrance is guarded by a complex system of bristle-like hairs, stalked glands, and a valve-like door. Organisms do not make a deliberate entrance as was at one time supposed, but are suddenly and forcibly engulfed within the traps where they are subsequently digested. Short-stalked, stellate, glandular hairs, usually with 2 or 4 arms, occur within the traps.

Axis

Scape and Rhizome

Transverse sections of the axis of the inflorescence of *U. montana* Jacq. show the xylem and phloem to be separate from one another as in *Genlisea ornata* Mart. Cortex somewhat lacunar, bounded internally by an endodermis surrounding a ring of fibrous mechanical elements. Scattered strands of phloem occur in the mechanical ring and also embedded in the parenchymatous pith. **Xylem** elements occur on the inside of the mechanical ring. Thick portions of the rhizome of *U. montana* similar in structure. Axis of *U. vulgaris* Linn. and *U. minor* Linn. exhibiting a somewhat similar but more reduced structure, with but little mechanical tissue.

4. POLYPOMPHOLYX

Members of this genus resemble and are provided with traps similar to those of *Utricularia.* The following anatomical features are recorded by Solereder. Foliage leaves of *P. multifida* F. v. M. and *P. tenella* Lehm. provided with stomata on both surfaces and a median vascular bundle containing only one vessel. In the axis, as in that of *Utricularia*, the phloem and xylem do not form definite bundles, but alternate strands of each of these kinds of tissue are attached to a ring of fibre-like sclerenchyma. The primary cortex includes large intercellular spaces, those at the points of attachment of the leaves and stolons being separated from one another by lamellae each consisting of a single layer of cells.

5. BIOVULARIA

The structure of this genus resembles that of the smaller species of *Utricularia.*

Genera Described

Biovularia, Genlisea, Pinguicula, Polypompholyx, Utricularia.*

* Represented in the Kew slide collection.

Literature

On General Anatomy

Hutchinson and Dalziel 1116, Lloyd 1383, McIntyre and Chrysler 1465.

201. COLUMELLIACEAE

SUMMARY

Small trees or shrubs belonging to the single genus *Columellia* which occurs on the Andes. No recent work on the general anatomy of the genus appears to have been done, and the following information is quoted from Solereder, whose description was based on an examination of *C. serrata* Rusby.

LEAF

Dorsiventral. Simple, unicellular, adpressed **hairs** present on the lower surface. **Stomata** confined to the lower surface; surrounded by rather numerous epidermal cells. A single layer of **hypoderm** present beneath the upper epidermis. Leaf-trace bundle consisting of an arc of xylem and phloem.

AXIS

STEM

Cork arising from a succession of phellogens at the outer limit of the phloem; consisting of layers of radially elongated, suberized cells alternating with radially compressed cells with cellulose walls. **Xylem** including vessels with scalariform perforation plates and fibres with bordered pits. Cluster and solitary **crystals**, the latter resembling styloids, present in the primary cortex and pith.

TAXONOMIC NOTES

Solereder has drawn attention to the fact that the taxonomic position of the Columelliaceae is not well established. He points out that the occurrence of scalariform perforation plates in the vessels, and of wood fibres with bordered pits, does not favour a very close relationship to the Gesneriaceae.

GENUS DESCRIBED

Columellia.

202. GESNERIACEAE

(FIG. 232 on p. 998; FIG. 233 on p. 1000)

SUMMARY

(i) GENERAL

A mainly tropical and sub-tropical family, consisting chiefly of herbs, but including some shrubs and small trees. Some members of the family exhibit interesting peculiarities in their external morphology. Here may be mentioned the reduction or suppression of one of the cotyledons. Also, we have been reminded by Hill (972) that, in species such as *Streptocarpus dunnii* Mast., *S. polyanthus* Hook. and *S. wendlandii* Hort., the cotyledon retains its power of growth in the basal region and becomes so large that it constitutes not only the principal foliar organ, but virtually the whole plant. The flowers arise from its midrib. In other species the opposite leaves are unequal in size. Tuberous rhizomes and scaly stolons serve as vegetative reproductive organs in certain species.

The leaf is dorsiventral in all investigated species. The simple, uniseriate **hairs** frequently have much-thickened terminal cells. Stalked glandular hairs also occur. The cells of the **epidermis,** especially on the upper surface of the leaf, are often very large and serve for water-storage. In other species, enlarged cells of the **hypoderm** or mesophyll serve the same purpose. The **stomata** are usually cruciferous, the guard cells often being smaller than those of the epidermis. *Napeanthus* has stomata in groups like those of the Begoniaceae. The stem of the herbaceous species sometimes contains a ring of collateral vascular bundles, but these generally become united by secondary, interfascicular tissue to form a continuous cylinder. The **cork** varies in its seat of origin. The **pericycle** contains a variable amount of sclerenchyma. **Medullary bundles** occur in a few genera, and **cortical bundles** in species of *Rhynchoglossum.* **Crystals** are frequent and very diverse in form. **Secretory canals** accompany the xylem in *Klugia*, *Monophyllaea*, and *Rhynchoglossum.*

(ii) Wood

Vessels typically small, with a tendency to radial multiples that produce a radial pattern, perforations simple, intervascular pitting alternate and small to minute, pits to parenchyma usually similar, members of medium length. **Parenchyma** absent or scanty paratracheal. **Rays** 2–17 cells wide, usually with very few uniseriates and composed entirely of square or upright cells. **Fibres** septate, with simple pits, moderately to extremely short. **Vascular tracheids** present.

Leaf

Dorsiventral in all investigated species of *Aeschynanthus*, *Chirita*, *Columnea*, *Episcia*, *Gesneria*, *Hemiboea*, *Nematanthus*, *Ramondia*, *Rhytidophyllum*, *Streptocarpus* (cotyledon). **Hairs** (Fig. 232 H). (i) Simple, uniseriate, sometimes situated on pedestals, but very frequently with the terminal cells more strongly thickened (calcified or silicified according to some authorities) than the remainder, the lumina in some cases being almost completely obliterated by thickening. Additional cells, besides the terminal ones, sometimes with the lumina filled up in the same way. Cells of the uniseriate hairs frequently filled with red or blue sap. Uniseriate hairs with hooked terminal cells recorded in *Epithema* by Schmidt (2038). (ii) Glandular hairs (Fig. 232 E and H), with stalks of varied length and heads divided by vertical walls into 2–6 or more cells. Hairs of this type often exhibit a wide range of variation even within a species. Glandular hairs recorded in *Acanthonema*, *Achimenes*, *Aeschynanthus* (sometimes in shallow depressions), *Chirita*, *Columnea*, *Episcia*, *Epithema* (sometimes hammer-shaped (Schmidt 2038)), *Gesneria*, *Gloxinia*, *Hemiboea*, *Isoloma*, *Jerdonia*, *Klugia*, *Loxonia*, *Monophyllaea*, *Napeanthus*, *Nematanthus*, *Phylloboea*, *Platystemma*, *Primulina*, *Rhynchoglossum*, *Saintpaulia*. Peltate glands, capable of secreting calcium carbonate, recorded in *Monophyllaea*. **Epidermis,** especially on the upper surface, sometimes composed of enlarged water-storage cells in species of *Episcia*, *Gesneria*, *Napeanthus* (both surfaces), *Tydaea*. Cells of the upper epidermis with straight, and those of the lower epidermis with slightly sinuous, anticlinal walls in *Hemiboea*, according to

Solereder (2161). A coarsely granular cuticle noted in some species of *Hemiboea*. **Hypoderm,** in a few instances consisting of several layers, also serves for water storage in species of *Aeschynanthus*, *Chirita*, *Codonanthe*, *Columnea*, *Hemiboea* (pro parte), *Monophyllaea*, *Nematanthus*, *Streptocarpus*. More or less elongated 'spicular cells', sometimes with pitted walls, noted by Solereder (2161) in the hypoderm of *Hemiboea*, but not in *H. follicularis* C. B. Clarke. 'Spicular cells' also recorded in *Stauranthera*. **Stomata** often very large; cruciferous, with the 3 subsidiary cells smaller than those of the epidermis; confined to the lower surface in *Hemiboea*; guard cells in all of the species of the same genus (except *H. follicularis*) examined by Solereder (2161) provided with radial striations. Stomata of *Napeanthus* usually arranged in groups very similar to those of the Begoniaceae, each group consisting of 2–18 pairs of guard cells accompanied by subsidiary cells. **Mesophyll** in *Jerdonia*, *Monophyllaea*, *Napeanthus*, *Saintpaulia*, and *Streptocarpus* said by Solereder to be composed of rounded cells united to one another by short peg-like processes. A single layer of short palisade cells recorded by Solereder (2161) in *Hemiboea*. Vascular bundles of the **veins** not usually accompanied by sclerenchyma, but a few fibres noted in this region by Solereder (2161) in *H. gracilis* Franch. Larger veins of *Jerdonia*, *Klugia*, *Loxonia*, *Napeanthus*, *Rhynchoglossum* including 2 collateral bundles, either with the xylem groups directed towards one another, or both with the xylem on the adaxial side. Five meristeles recorded by Chifflot (394) in the midrib of *Klugia notoniana* A. DC.

Petiole (Fig. 232 A–D and F) said by Solereder to be supplied at the base by a single leaf-trace bundle in numerous genera, accessory strands being present as well at a higher level. Three leaf-trace strands reported in species of *Alloplectus*, *Besleria*, *Columnea*, *Episcia*, *Nematanthus*; and a relatively large number of separate strands in *Klugia*. Petiole, in transverse sections through the distal end in material examined at Kew, exhibiting the following structure. (i) A shallow, more or less continuous, vascular crescent, with additional, widely spaced strands towards the wings, and 2 approximately centric, adaxially placed bundles between the ends of the crescent in *Achimenes warscewicziana* Regel. (ii) Somewhat similar to (i), but vascular crescent rather more dissected, and bundles between the ends of the crescent more numerous and complex in structure in *Gesneria allagophylla* Mart. and *Gloxinia* sp. (horticultural variety) (Fig. 232 C). (iii) Similar to (ii) but with additional scattered bundles towards the adaxial surface, besides those between the ends of the crescent, in *Isoloma hirsutum* Regel. (Fig. 232 D) and *Sinningia speciosa* Hiern. (iv) Similar to (iii), but with no bundles between the ends of the crescent or towards the adaxial surface in *Ramondia pyrenaica* Rich. (Fig. 232 A). (v) A small, shallow, vascular crescent in *Columnea gloriosa* Sprague. (vi) A deep crescent of vascular tissue, more or less dissected into separate strands and accompanied by scattered adaxial bundles, in *Streptocarpus* sp. (Fig. 232 F). (vii) A small, deep, vascular crescent, with xylem vessels in rather widely spaced radial rows, accompanied by accessory strands in the wings in *Aeschynanthus parvifolius* R. Br. Petiolar vascular strands in all of the above species, not accompanied by 'pericyclic' sclerenchyma. Ground-tissue of the petiole usually composed of thin-walled, parenchymatous cells, except in *Columnea gloriosa* with scattered, pitted, sclerosed cells; spongy in

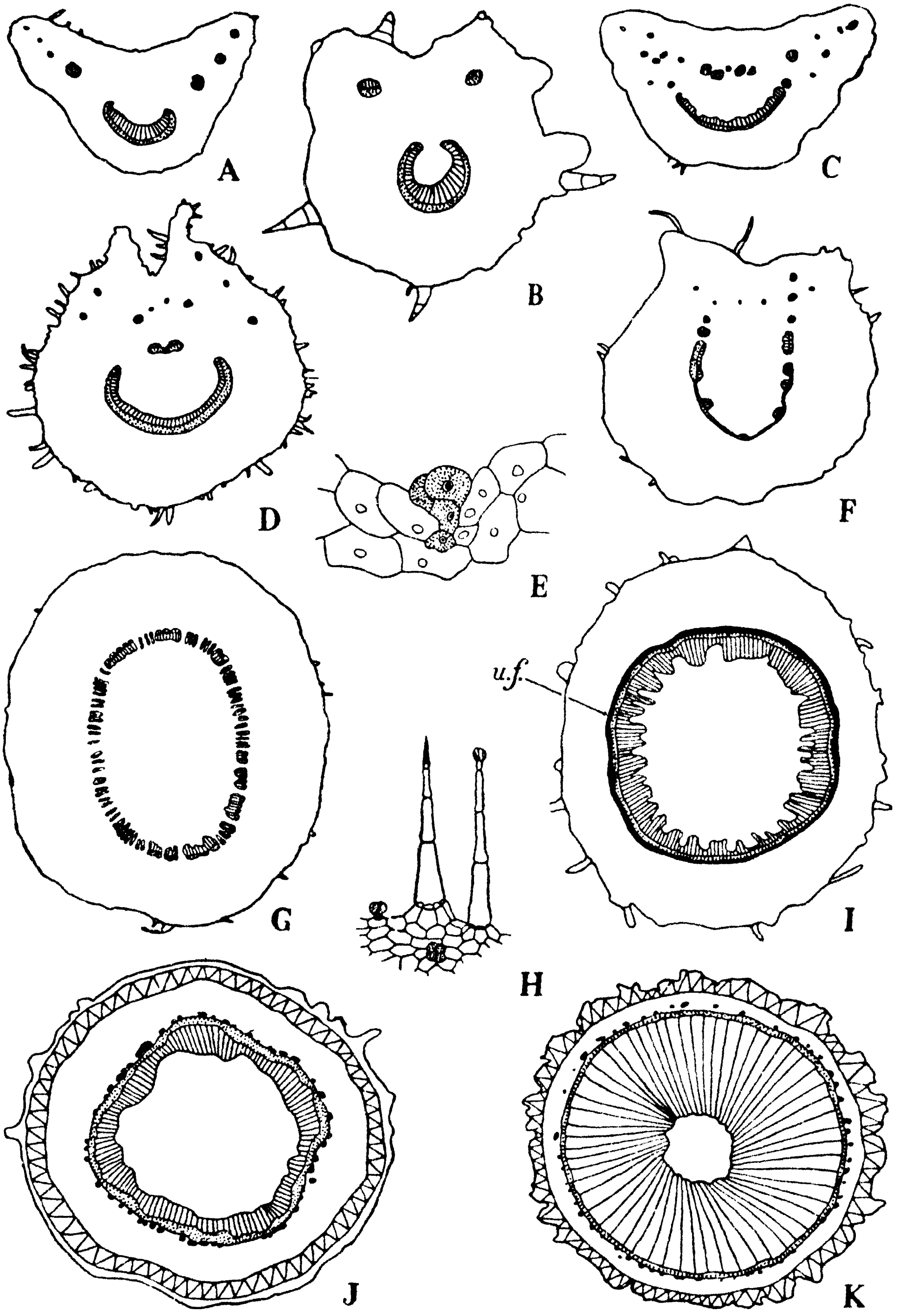


FIG. 232. *GESNERIACEAE*

A, *Ramondia pyrenaica* Rich. Petiole ×5. B, *Rhabdothamnus solandri* A. Cunn. Petiole ×52. C, *Gloxinia* sp. Petiole ×4. D, *Isoloma hirsutum* Regel. Petiole ×13. E, *Aeschynanthus parvifolia* R. Br. Glandular hair ×233. F, *Streptocarpus* Ornamental 'variety'. Petiole ×9. G, *Sinningia speciosa* Hiern. Stem ×9. H, *Achimenes glandiflora* DC. Hairy covering. I, *A. warscewicziana* Regel. Garden 'variety'. Stem ×18. J, *Columnea gloriosa* Sprague. Stem ×25. K, *Rhabdothamnus solandri* A. Cunn. Stem ×15.

u.f. Unlignified fibres.

Ramondia pyrenaica. **Secretory canals** (see also under 'Axis') of variable diameter, and with resinous or oily contents, accompany the xylem of the vascular bundles in *Klugia*, *Monophyllaea*, and *Rhynchoglossum*. **Crystals** variable in form and frequency in different genera and species; some described by Solereder as resembling an envelope; clusters, small needles, and prisms also known to occur; particularly elongated crystals recorded in the mesophyll of *Phylloboea*. A single cluster or a number of smaller crystals present in each palisade cell in *Hemiboea* (except *H. gracilis*), according to Solereder (2161). Acicular crystals observed at Kew in the petiolar ground-tissue of *Gloxinia*, and small clusters in the corresponding position in *Aeschynanthus parvifolius*.

AXIS

STEM (Fig. 232 G, I, J, K)

Cork arising superficially in species of *Alloplectus*, *Columnea* (Fig. 232 J), *Cyrtandra*, *Isoloma*, and *Rhabdothamnus* (Fig. 232 K), or internally to the pericyclic sclerenchyma in *Bellonia*, *Pentarhaphia*, *Rhytidophyllum*. Cork cells thin-walled in species of *Columnea*, *Isoloma*, and *Pentarhaphia*, with the outer tangential walls thickened in *Bellonia*; some of the cells with thickenings to the inner tangential walls in *Alloplectus* and *Cyrtandra*. Primary **cortex** differentiated into an outer part consisting of small cells with moderately thick walls and an inner part of much larger cells with thinner walls in species of *Achimenes* (walls of outer cells thicker than in the other genera), *Gesneria*, *Gloxinia*, *Streptocarpus*. Cortex containing sclerosed cells in species of *Aeschynanthus*, *Alloplectus*, and *Columnea*. **Endodermis** more or less clearly differentiated in species of *Achimenes*, *Aeschynanthus* (inner and tangential walls strongly thickened), *Ramondia*. **Pericycle** including more or less elongated, pitted, sclerenchymatous cells with yellow walls in species of *Bellonia*, *Cyrtandra*, *Pentarhaphia*, *Rhytidophyllum* according to Solereder. The following types of pericyclic structure noted at Kew in 1 or 2 species of each of the genera mentioned. (i) Solitary or small strands of thick-walled fibres with small lumina in *Columnea* (Fig. 232 J) and *Rhabdothamnus* (Fig. 232 K); (ii) an interrupted ring of fibres with wide lumina in *Gloxinia* and *Isoloma*; (iii) a fairly broad, continuous ring of fibres with wide lumina in *Achimenes* (Fig. 232 I) and *Gesneria*; (iv) pericycle wholly sclerosed in *Ramondia*; (v) pericyclic sclerenchyma absent from *Aeschynanthus* and *Sinningia*.

Vascular system exhibiting a fairly wide range of structure in transverse sections, but bundles generally becoming united by interfascicular, prosenchymatous elements to form a continuous cylinder. **Xylem.** Vessels mostly in fairly numerous, short, radial rows in species of *Achimenes* (especially in the primary xylem), *Gesneria*, *Gloxinia* (vessels crowded), *Isoloma*, *Sinningia*; very infrequent, but tending to be in radial rows in *Columnea*; very infrequent, mostly solitary, but some in pairs or small clusters in *Aeschynanthus*. Vessels with simple perforations. **Medullary bundles** recorded in *Klugia*, *Monophyllaea*, and *Rhynchoglossum*. A single, centric **cortical bundle** also said by Solereder to occur in the ridged stem of *Rhynchoglossum obliquum* Blume.

Pith wide and composed of large, thin-walled cells in species of *Achimenes*, *Gesneria*, *Gloxinia*, *Isoloma*, *Ramondia*, *Sinningia*. **Crystals** very variable in form and frequency in different genera and species. Large druses noted in

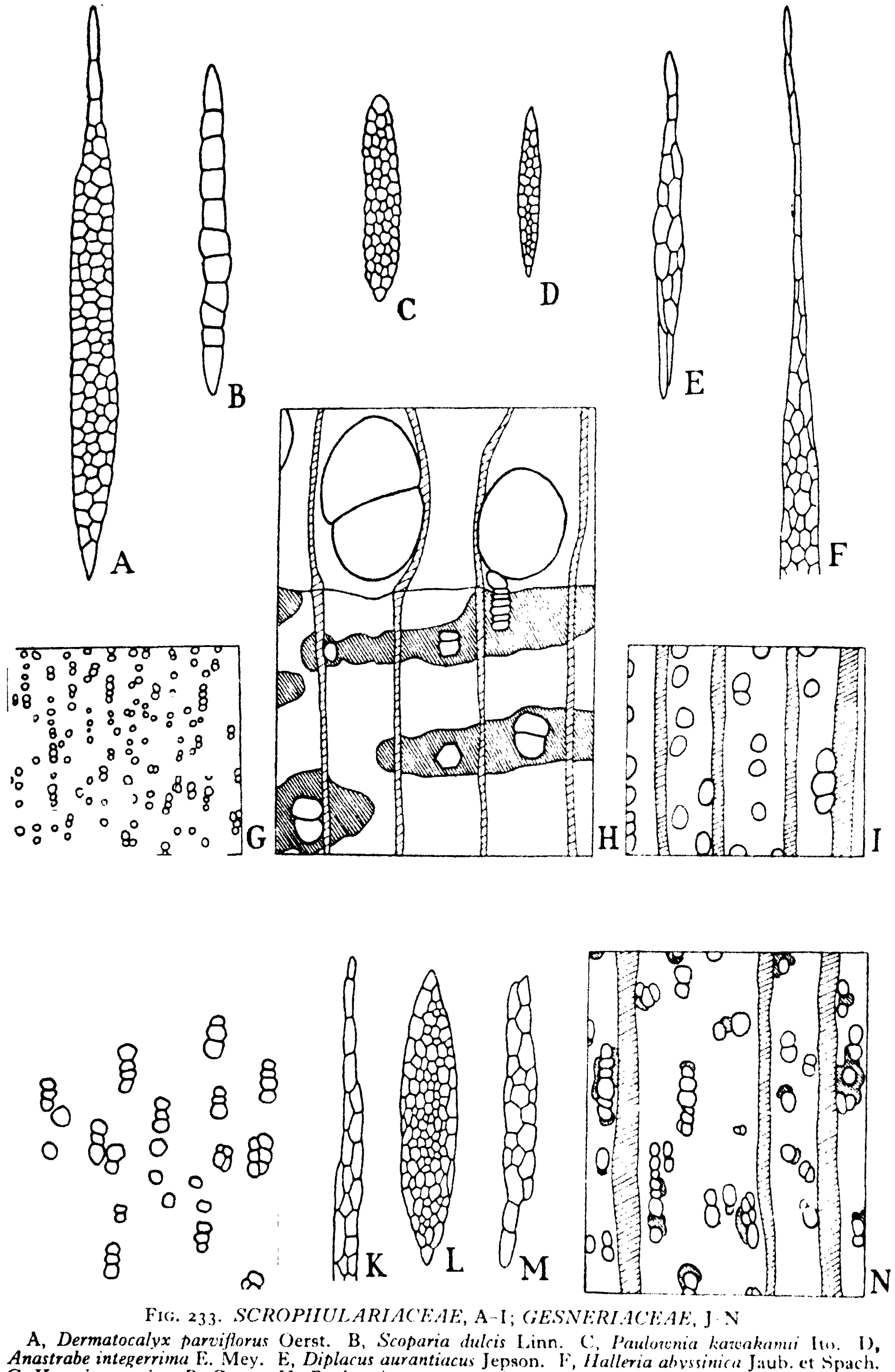


FIG. 233. *SCROPHULARIACEAE*, A–I; *GESNERIACEAE*, J–N

A, *Dermatocalyx parviflorus* Oerst. B, *Scoparia dulcis* Linn. C, *Paulownia kawakamii* Ito. D, *Anastrabe integerrima* E. Mey. E, *Diplacus aurantiacus* Jepson. F, *Halleria abyssinica* Jaub. et Spach. G, *Veronica speciosa* R. Cunn. H, *Paulownia tomentosa* (Thunb.) Steud. I, *Halleria abyssinica* Jaub. et Spach. J, *Rhytidophyllum tomentosum* (L.) DC. K, *R. tomentosum* (L.). DC. L, *Gesneria* sp. M, *Solanophora calycosa* Donn. Smith. N, *Gesneria* sp.

the pith of *Achimenes*; acicular and rather elongated cubical crystals in the pith of *Columnea* and *Gloxinia* (see also under 'Leaf'). **Secretory canals,** of schizogenous origin and with resinous or oily contents, said by Wonisch (2455) to accompany the xylem in the main ring of vascular strands and frequently that of the medullary bundles as well in *Klugia*, *Monophyllaea*, and *Rhynchoglossum*. This has been confirmed in *Klugia* and *Monophyllaea* by Chifflot (394).

PEDUNCLE

Transverse sections through the peduncle of various species of *Streptocarpus* examined at Kew showed the **vascular bundles** remaining individually distinct but united in the form of a circle by radial rows of secondary, quadrangular, prosenchymatous elements. **Pith** in some species of *Streptocarpus* becoming hollow.

WOOD (Fig. 233 J–N)

Vessels typically small (less than 100 μ mean tangential diameter) and sometimes extremely small (less than 25 μ), e.g. in *Gesneria* and *Rhabdothamnus*, but medium-sized (100–200 μ) in *Drymonia spectabilis* Mart.; solitary and in numerous multiples, the multiples often of 4 or more cells and producing a radial pattern in *Rhabdothamnus*, *Rhytidophyllum* (Fig. 233 J), and *Solenophora*; mostly 15–20 per sq. mm., but up to 80 per sq. mm., in *Rhabdothamnus*. Perforations simple, often with wide rims. Intervascular pitting alternate, typically very small to minute, but rather larger in *Drymonia*; pits to ray and wood parenchyma typically similar to the intervascular pitting, but occasionally elongated in *Solenophora*, sometimes unilaterally compound in *Besleria* and with some simple pits in *Alloplectus* (2158) and *Drymonia*. Mean member length 0·4–0·5 mm. **Parenchyma** typically absent or extremely sparse and limited to a few cells round the vessels; paratracheal parenchyma rather more abundant in *Cyrtandra* (1154), *Gesneria* (Fig. 233 N), and *Solenophora*; Williams (2430) describes the parenchyma of *Drymonia* sp. as aliform to confluent, but it is extremely sparse in the material examined of *D. spectabilis*. Strands usually of 2–4 cells. Storied, together with all the other elements, in *Cyrtandra* (1154). **Rays** absent from *Besleria*; 2–17 cells wide in the other genera, up to 6 cells in *Gesneria*, 12 cells in *Drymonia spectabilis*, and 17 cells in *Cyrtandra* (1154), rarely more than 3 cells wide in the other genera examined; usually less than 1 mm. high, except in *Cyrtandra* (1154), *Drymonia*, and *Rhytidophyllum*; uniseriate rays usually very few or absent, but moderately numerous in *Solenophora* and *Rhytidophyllum* and composed of square and upright cells; 1–3 rays per mm.; composed almost entirely of square or upright cells, except in *Cyrtandra* (1154), and sometimes with 4 or more marginal rows of upright cells, e.g. in *Solenophora* and *Rhytidophyllum*; sometimes with sheath cells, e.g. in *Gesneria*. **Fibres** septate in all the genera examined and, according to Solereder, in *Alloplectus*, *Bellonia*, *Cyrtandra*, and *Pentarhaphia*; with numerous, small, simple pits, equally abundant on both radial and tangential walls; walls typically thin, but occasionally moderately thick, e.g. in *Gesneria*; storied, together with all the other elements, in *Cyrtandra* (1154). Mean length in *Rhabdothamnus* 0·45–0·75 mm. **Vascular tracheids** often present.

TAXONOMIC NOTES

Wonisch (2455) has pointed out that *Klugia*, *Monophyllaea*, and *Rhynchoglossum* are sharply differentiated from other genera of the family by the presence of secretory canals in the stem and leaf.

ECONOMIC USES

Many herbaceous members of the family, such as species of *Gloxinia*, *Ramondia*, and *Streptocarpus*, &c., are cultivated for ornamental purposes.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Acanthonema, Achimenes,* Aeschynanthus,* Bellonia, Besleria, Chirita, Columnea,* Cyrtandra, Episcia, Epithema, Gesneria,* Gloxinia,* Hemiboea, Isoloma,* Jerdonia, Klugia, Loxonia, Monophyllaea, Napeanthus, Nematanthus, Pentarhaphia, Phylloboea, Platystemma, Primulina, Ramondia,* Rhynchoglossum, Rhytidophyllum, Saintpaulia, Sinningia,* Stauranthera, Streptocarpus,* Tydaea.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

(Alloplectus), (Bellonia), Besleria, (Cyrtandra), Drymonia, Gesneria, (Pentarhaphia), Rhabdothamnus, Rhytidophyllum, Solenophora.

LITERATURE

(i) *On General Anatomy*

Chifflot **394**, Hill **972**, Schmidt **2038**, Solereder **2161**, Wonisch **2455**.

(ii) *On Wood Structure*

Janssonius **1154**, Record **1809**, **1851**, Record and Hess **1886**, Tupper **2295**, Williams **2430**.

203. BIGNONIACEAE

(FIG. 234 on p. 1004; FIG. 235 on p. 1006; FIG. 236 on p. 1008; FIG. 237 on p. 1010)

SUMMARY

(i) GENERAL

A tropical and sub-tropical family which includes many lianes, as well as some shrubs and a few herbs. The most interesting anatomical feature is the occurrence, particularly amongst the lianes, of several types of **anomalous secondary thickening.** These include the development of wedge-shaped masses of phloem in the xylem; the occurrence of secondary rings of xylem and phloem in the secondary cortex or pericycle; fissured xylem; inversely orientated bundles abutting on the pith. In some instances more than one of these anomalies may occur in a single stem, but it is usual for the phloem wedges to appear first, the others being subsequent developments. Variations in the anomalous structure are a valuable aid to the identification of genera. The leaf is usually dorsiventral, although isobilateral structure is not unknown. The external **hairs** include a variety of glandular and non-glandular forms (Fig. 234). **Stomata,** confined to the lower surface, are usually surrounded by a fairly large number of ordinary epidermal cells, but rubiaceous and caryophyllaceous types have been reported in a few genera. **Crystals** are mostly in the form of small octahedra, prisms, or needles. Large solitary or cluster crystals are rare, although sphaerocrystals of unidentified material have been reported from specimens preserved in spirit, and nuclear crystalloids in the leaf of a few genera. The vascular structure of the **petiole** exhibits a wide range of structure. No particularly characteristic features have been reported from the young stem, apart from the anomalous secondary thickening described above.

(ii) WOOD

Vessels small to medium-sized, sometimes with a tendency to clusters of very small vessels, particularly in the climbers, occasionally ring-porous and with spiral thickening, perforations typically simple, but with a few characteristic multiperforate plates in some genera, intervascular pitting minute to moderately large, pits to parenchyma similar, members usually moderately to very short, occasionally of medium length. **Parenchyma** paratracheal, varying from narrowly vasicentric to abundant aliform and confluent types often storied or almost storied. **Rays** in the arboreal species 1–4 cells wide, short and homogeneous and often storied; in the climbers usually up to 5–13 cells wide and composed of either procumbent cells only or of square to upright cells only. **Fibres** septate in the climbers and a few other species, pits small and simple or with very small borders, of medium length to moderately short.

LEAF

Usually dorsiventral, but isobilateral structure recorded in *Kigelia*. **Hairs** (Fig. 234) include glandular and non-glandular kinds, the latter usually in the form of simple unicellular or uniseriate trichomes, with relatively large lumina and fairly thick walls. Branched, multicellular hairs recorded in *Adenocalymma*, *Amphilophium*, *Arrabidaea*, *Pithecoctenium*, *Tabebuia*, *Tecoma* (Fig. 234 A), *Zeyheria*, those in *Tabebuia* sometimes with sympodial branching, and those of *Zeyheria* with uniseriate stalks and heads of radiating cells. Glandular hairs shortly stalked and scale-like in *Amphicome* (Fig. 234 B), *Amphilophium*, *Catalpa*, *Chilopsis* (Scott 2070), *Cuspidaria*, *Dolichandrone*, *Phyllarthron*, *Pithecoctenium*, *Pyrostegia* (Fig. 234 C), *Spathodea* (Rao 1773), *Tabebuia*, or with longer stalks in *Cremastus*, the secretion in this genus making the leaf sticky. Glands of *Phyllarthron* sometimes secrete a substance like varnish which forms a coating on the upper surface of the leaves; those of *Jacaranda* and *Spathodea* serve as hydathodes; those of *Tabebuia* sometimes secrete calcium carbonate. Somewhat similar glands, but with an accumulation of secreted material between the cuticle and the cellulose head, recorded in *Dolichandrone* and *Stizophyllum*, sometimes giving rise to transparent dots in the leaf. Circular, disk-shaped, slightly depressed glands also widely distributed, notably in *Adenocalymma* (Fig. 234 E) and *Campsis*; disk-shaped, slightly raised glands in *Kigelia*. **Cuticle** smooth, striated, or, in *Colea*, with verrucose thickenings. **Epidermis** composed of cells with straight or sinuous anticlinal walls; silicified and papillose in *Kigelia*. Epidermal cells on the upper side of the leaf unusually tall in *Catalpa*, *Colea*, *Crescentia*; sometimes with horizontal partitions in *Tabebuia*. One or more layers of **hypoderm** recorded in species of *Pandorea* and *Schlegelia*. **Stomata** confined to the lower surface; each pair of guard cells surrounded by a considerable number of ordinary epidermal cells in species of *Amphicome*, *Amphilophium*, *Campsis*, *Catalpa*, *Clytostoma*, *Cuspidaria*, *Eccremocarpus*, *Incarvillea*, *Melloa*, *Pandorea*, *Stizophyllum*, *Tabebuia*, *Tecomaria*; rubiaceous in species of *Adenocalymma*, *Arrabidaea*, *Colea*, *Schlegelia*; caryophyllaceous in *Kigelia*. **Mesophyll.** A layer of cells with very wide lumina occurs at the boundary between palisade and spongy tissue in *Campsis* and *Tecomaria*. Groups of silicified cells present in *Kigelia*. Sclerenchymatous fibres ('spicular cells') recorded in the mesophyll of *Colea*, *Crescentia*, *Phyllarthron*. **Petiole** (Fig. 235 A–C), in transverse sections through the distal end of the few species examined at Kew, exhibiting a closed or nearly closed vascular ring, sometimes dissected into separate bundles. Vascular ring quite or almost continuous,

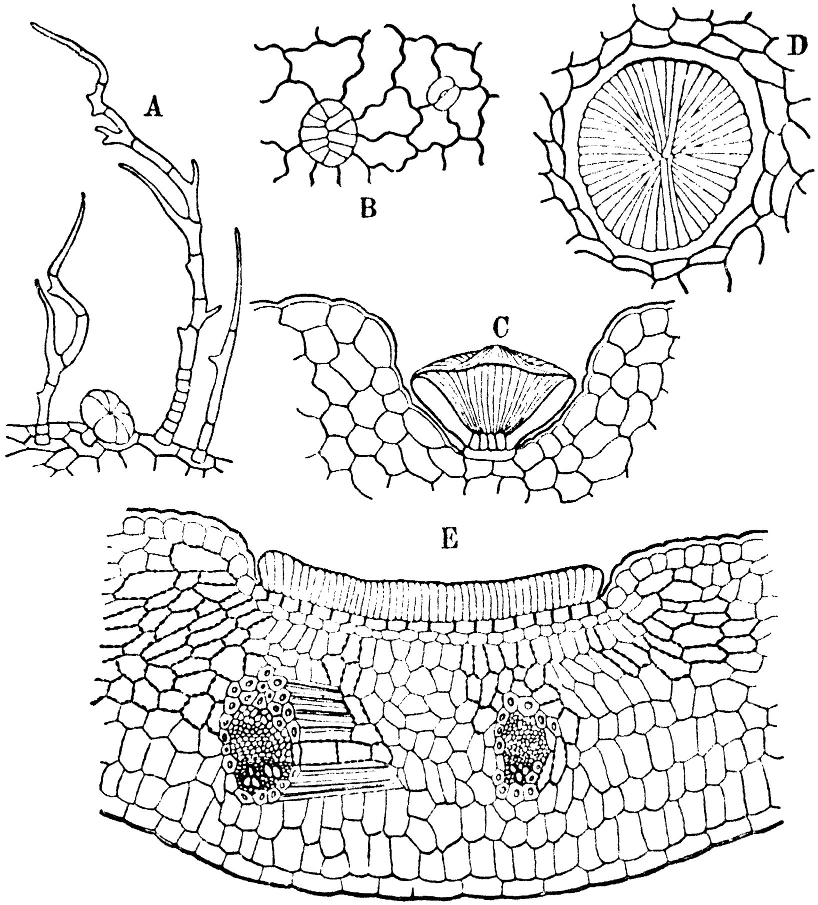


FIG. 234. *BIGNONIACEAE*

Hairs of: A, *Tecoma mollis* H. B. et K.; B, *Incarvillea diffusa* Royle (syn. *Amphicome arguta* Royle); C–D, *Pyrostegia venusta* (Ker-Gawl.) Miers (syn. *Bignonia tecomaeflora* Rusby); E, Patelliform gland of *Adenocalymma impressum* (Rusby) Sandwith (syn. *Bignonia impressa* Rusby) (in the figure the lower side of the leaf is directed upwards).—By Solereder.

but somewhat flattened towards the adaxial side, in species of *Campsis*, *Catalpa* (much more dissected in *C. bignonioides* Walt. (Fig. 235 A) than in *C. speciosa* Warder), *Crescentia*, *Kigelia* (Fig. 235 C), *Parmentiera*, *Tecomaria*; vascular system more dissected in species of *Clytostoma*, *Eccremocarpus* (Fig. 235 B), and *Incarvillea*. **Crystals** in the form of small octahedra, prisms, or needles. Large solitary or cluster crystals rare. Sphaerocrystals of an unidentified substance recorded in spirit material of *Pithecoctenium* and *Pyrostegia*. Nuclear crystalloids occur in the epidermis and mesophyll in species of *Arrabidaea*, *Catalpa*, *Jacaranda*.

AXIS

YOUNG STEM (Fig. 235 E, G, H, I)

The most noteworthy feature is the widespread occurrence, especially amongst lianes, of the various types of **anomalous structure** described on p. 1009. **Cork** arising from 1 to several layers below the epidermis in species of *Catalpa*, *Crescentia*, *Jacaranda*, *Oroxylon*, but its seat of origin not very fixed for a given species; more deeply seated in the primary cortex in *Tabebuia*. Cork cells often with wide lumina and thin walls, and, in some species, stratified into layers with thick and thin walls respectively, e.g. in *Crescentia cujete* Linn. Primary **cortex** sometimes collenchymatous, e.g. in *Catalpa bignonioides* Walt., or thin-walled, e.g. in *Jacaranda ovalifolia* R. Br.; stone cells, sometimes arranged in a ring, also occur in this region in certain species. Sclerenchyma strands present in the ribs of the angular branches of *Eccremocarpus*, *Haplolophium*, *Pithecoctenium*, *Pleonotoma*.

Pericycle usually containing strands of sclerenchyma, but a composite, continuous ring not recorded. Secondary **phloem** stratified into fibrous and soft portions in species of *Crescentia*, *Kigelia*, *Parmentiera*, *Tecoma* (Fig. 235 I), and probably in other genera. **Xylem** in the form of a continuous cylinder traversed by narrow rays in the genera examined at Kew; broad primary rays occur in lianes. Vessels usually with simple perforations, but reticulate plates also recorded (see 'Wood'). **Pith** generally lignified in tropical species, and homogeneous in *Campsis radicans* Seem. Small, spindle-shaped **crystals** noted at Kew in the cortex, phloem, and pith of *Parmentiera careifera* Seem., in the cortex and phloem of *Crescentia cujete* Linn., and in the phloem only in *Kigelia africana* Benth.; rhomboidal, solitary crystals seen in the cortex and phloem of *Tabebuia*. See also under 'Leaf'.

The **developmental anatomy** of *Chilopsis* has been described by Scott (2070).

WOOD (Fig. 236)

Vessels mostly medium-sized (100–200 μ mean tangential diameter), sometimes smaller (50–100 μ), e.g. in species of *Anemopaegma*, *Cotema*, *Crescentia*, *Enallagma*, *Mayodendron*, *Parmentiera*, and *Stenolobium*; more than 200 μ in some species of *Adenocalymma*, *Arrabidaea*, *Callichlamys*, *Disticella*, *Jacaranda*, *Potamoganos*, and *Stereospermum*. Solitary and in small multiples of 2 or 3 cells, sometimes with a tendency to tangential rows, e.g. in some species of *Catalpa*, *Chilopsis*, *Godmania*, *Jacaranda*, and *Tecoma* or an oblique pattern, and sometimes in irregular clusters of small vessels, e.g. in *Catalpa* (Fig. 236 E); similar clusters often present in the climbers, in which the vessels often tend to be of 2 distinct sizes, large and small (Fig. 236 J), tending to be of 2 sizes also in *Chilopsis*, in which minute, tracheid-like vessels occur in bands with parenchyma at the ring-boundaries. Mostly 5–20 per sq. mm., but fewer in some species of *Catalpa*, *Deplanchea*, *Dolichandrone*, *Jacaranda*, *Kigelia*, *Oroxylon*, *Pajanelia*, *Stereospermum*, and *Tabebuia*. Ring-porous in *Bignonia* (1851), *Catalpa*, *Chilopsis*, and *Ferdinandia*, and in some of the lianes; spiral thickening sometimes present in the small vessels of *Campsis*, *Catalpa*, and *Chilopsis*. Perforations typically simple, but sometimes with a few horizontal multiperforate plates of the reticulate or foraminate types in some species of *Crescentia*, *Diplanthera*, *Ferdinandia*, *Jacaranda*, *Markhamia*, *Millingtonia*, *Oroxylon*, *Pajanelia*, *Stereospermum*, *Tabebuia*, and *Tecoma* (352). Intervascular pitting alternate, usually medium-sized, but very small to minute in some species of *Anemopaegma*, *Crescentia*, *Cydista*, *Enallagma*, *Heterophragma*, *Mayodendron*, *Newbouldia*, *Parmentiera*, *Redermachera*, *Schlegelia*, *Stenolobium*, and *Tabebuia*. Pits to ray and wood parenchyma

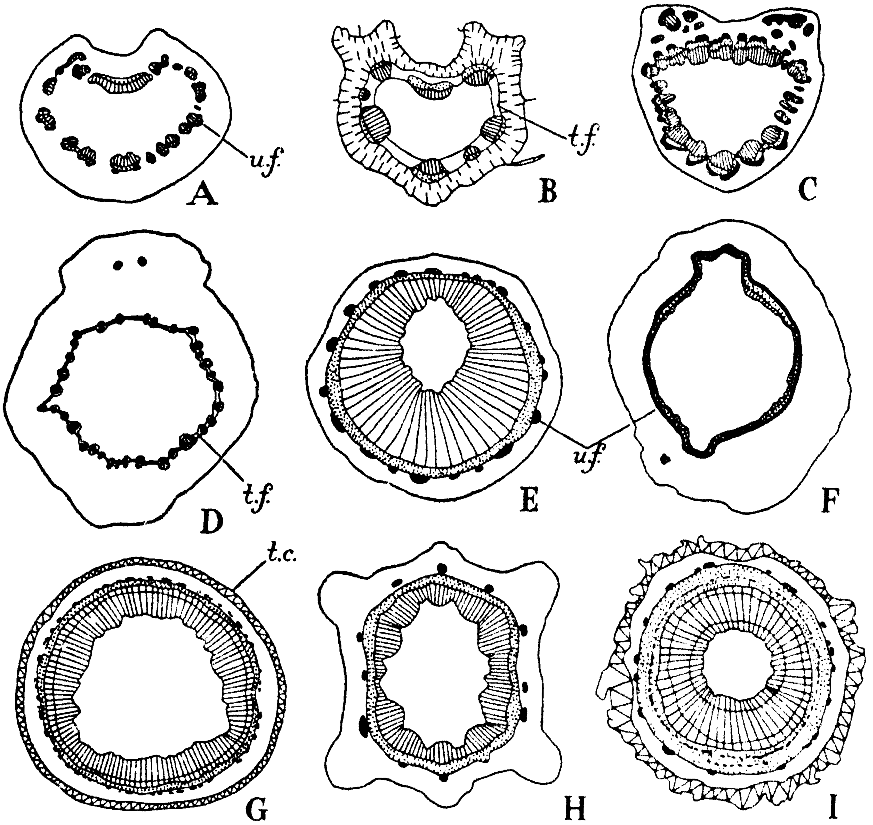


FIG. 235. *BIGNONIACEAE*, A–C, E, and G–I; *OROBANCHACEAE*, D and F

A, *Catalpa bignonioides* Walt. Petiole ×8. B, *Eccremocarpus scaber* R. et P. Petiole ×20. C, *Kigelia africana* Benth. Petiole ×8. D, *Orobanche hederae* Duby. Flower stalk ×6. E, *Incarvillea sinensis* Lam. Stem ×10. F, *Lathraea squamaria* Linn. Flower stalk ×6. G, *Catalpa bignonioides* Walt. Stem ×5. H, *Eccremocarpus scaber* Ruiz. et Pav. Stem ×14. I, *Tecoma capensis* Lindl. Stem ×12. *t.c.* Thin-walled cork. *t.f.* Thin-walled fibres. *u.f.* Unlignified fibres.

similar to the intervascular pitting, occasionally simple, e.g. in *Pajanelia rheedii* DC., or elongated, e.g. in *Catalpa longissima* (Jacq.) Seem. Tyloses often present, e.g. in *Adenocalymma*, *Catalpa*, *Couralia*, *Cydista*, *Ekmanianthe*, and *Paratecoma*; often with solid deposits; sulphur-yellow deposits of lapachol sometimes very abundant in *Tabebuia* and *Tecoma* and present in smaller quantities in some other genera; lapachol is not known to occur outside this family except in *Avicennia* (see *Trop. Woods*, **1**, 7–9, 1926). Gonggrijp (794) refers to silica in the tyloses of *Stereospermum suaveolens* DC. Mean member length 0·2–0·42 mm. **Parenchyma** paratracheal; principally vasicentric in the lianes and in *Catalpa* p.p. (Fig. 236 E), *Ekmanianthe*, *Enallagma*, *Paratecoma*, and *Stenolobium*; aliform to confluent in the other genera (Fig. 236 D, K, and M) and sometimes very abundant (Fig. 236 A); scanty paratracheal to vasicentric in *Anemopaegma*; occasionally in narrow terminal bands, e.g. in some species of *Cotema*, *Melloa*, *Stereospermum*, and *Tabebuia*. Crystals observed in very few species, e.g. *Stereospermum kunthianum* Cham. Strands most commonly of 2 or 4 cells, up to 8 cells in *Oroxylon*, and sometimes with a few fusiform cells, e.g. in *Newbouldia* and *Stereospermum*. Sometimes distinctly storied, e.g. in *Adenocalymma*, *Arrabidaea*, *Campsis*, *Cotema*, *Couralia*, *Crescentia*, *Disticella*, *Enallagma*, *Godmania*, *Martinella*, *Paratecoma*, *Tabebuia*, and *Tecoma*, and with a marked tendency to stories in several other genera. Occasional groups of sclerosed cells observed in a specimen of *Couralia toxophora* (Spruce) B. et H. **Rays,** except in the climbers, typically 2–4 cells wide; exclusively uniseriate in *Dolichandrone* p.p., e.g. *D. spathacea* (L. f.) K. Schum., *Enallagma*, and *Tabebuia longipes* Bak., and almost exclusively uniseriate in *Crescentia cujete* L. Uniseriates very few in genera with multiseriate rays and composed entirely or mainly of procumbent cells. Rays 4–11 per mm. Typically homogeneous (Kribs's Types II and III), but slightly heterogeneous (i.e. often with a single marginal row of square cells) in some species of *Catalpa*, *Chilopsis*, *Cydista*, *Diplanthera*, *Ferdinandia*, *Newbouldia*, and, according to Record and Hess (1888), in species of *Astianthus*, *Jacaranda*, *Paratecoma*, and *Tecoma*; with several marginal rows in *Schegelia* and *Stenolobium*. Crystals uncommon, observed only in *Cydista*, *Ferdinandia*, *Newbouldia*, and *Potamoganos*, and reported (1888) in *Tabebuia stenocalyx* Spr. et Stapf. Storied in at least some species of *Cotema*, *Couralia*, *Crescentia*, *Diplanthera*, *Godmania*, *Parmentiera*, *Tabebuia*, and *Tecoma*, and locally storied in other genera. In the climbers, rays typically high and 5–13 cells wide, but not more than 2 or 3 cells wide in *Callichlamys latifolia* (Rich.) K. Schum., *Macrodiscus lactiflorus* (Vahl.) Bur., *Memora caracasona* Schum., and *Schlegelia nicaraguensis* Standl., and exclusively uniseriate in *Melloa populifolia* (DC.) Bur. The broad rays usually homogeneous and accompanied by very few uniseriates; in the woods with narrower rays these may be high, with several marginal rows of square or upright cells and with more numerous uniseriates, as in *Schlegelia*, or composed entirely of square or upright cells, as in *Callichlamys* and *Macrodiscus*, or short and storied, as in *Melloa*. **Fibres** typically septate in the climbers, e.g. in *Adenocalymma*, *Anemopaegma*, *Arrabidaea*, *Campsis*, *Distictella*, *Macrodiscus*, *Martinella*, *Melloa*, *Memora*, *Petastoma*, *Pithecoctenium*, *Potamoganos*, *Schlegelia* (round the vessels only), and *Tecomaria* (2158); septate also in some species of *Catalpa*, e.g. *C. longissima* (Jacq.) Seem. and *C. punctata* Gris. (1888), and

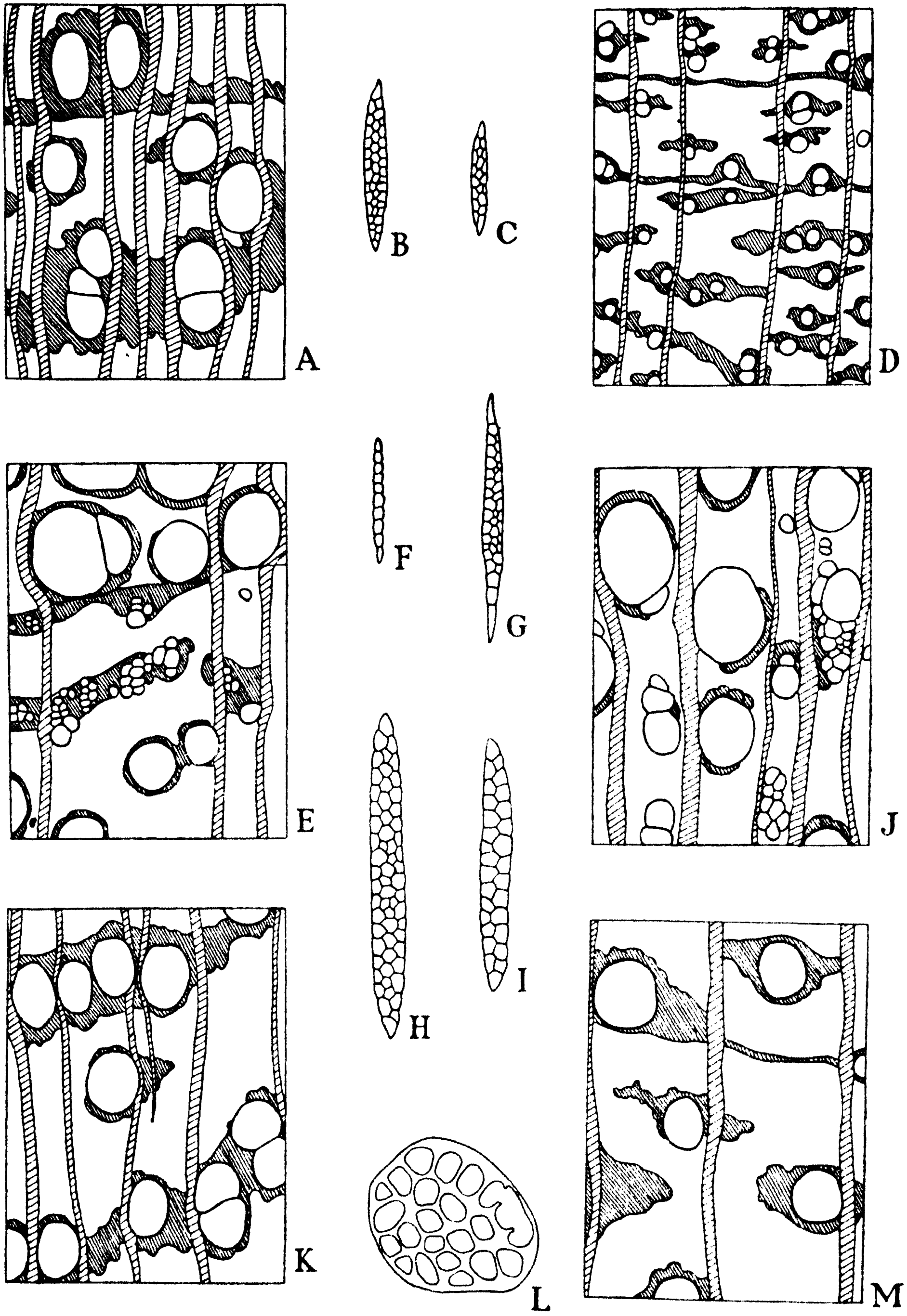


FIG. 236. *BIGNONIACEAE*

A, *Tabebuia pentaphylla* Hemsl. B, *Markhamia platycalyx* Sprague. C, *Godmania aesculifolia* Standley. D, *Parmentiera macrophylla* Standley. E, *Catalpa speciosa* Warder. F, *Enallagma latifolia* Small. G, *Cydista* sp. H, *Stereospermum neuranthemum* Kurz. I, *Tabebuia pentaphylla* Hemsl. J, *Petastoma broadwayi* Sprague et Riley. K, *Markhamia platycalyx* Sprague. L, *M. lutea* A. Chev. Foraminate perforation plate × 200. M, *Stereospermum chelonoides* DC.

occasionally in some species of *Cybistax* (1888) and *Stereospermum*. Pits typically numerous on the radial and very few on the tangential walls, simple or with very small borders. Walls varying from thin to thick, the latter sometimes mucilaginous. Mean length 0·7–1·15 mm.

ANOMALOUS STRUCTURE (Fig. 237 A–C)

The anomalies described below are known in some instances to occur in the root as well as the stem, but insufficient material has been examined to reveal how frequently this is so.

I. *Wedges of phloem in the xylem* (Fig. 237 A–B)

Stems which exhibit this type of structure when mature are provided with a normal ring of vascular bundles, with vessels of small diameter in the xylem, when young. The later-formed wood contains vessels of much larger diameter. As soon as this stage is reached 4 furrows appear in the xylem, extending almost to the central pith. In some species secondary and tertiary or further series of furrows arise between the primary ones during the subsequent development of the shoot, e.g. in species of *Amphilophium*, *Anemopaegma*, *Clytostoma*, *Cydista*, *Lundia*, *Phryganocydia*, *Pyrostegia*, *Tynnanthus*. Structure similar, but combined with successive rings of growth, in *Distictella*, *Glaziova*, *Haplolophium*, or with a fissured xylem mass in *Doxantha* and *Melloa*. The cambium is situated on the inside of the furrows, but not on the radial surfaces, and gives rise to phloem in the furrows. As the phloem increases in bulk the tissues must slide along the lateral surfaces of the furrows. This is facilitated by the development, beside the radial surfaces of the furrows, of fissures which subsequently become closed again. The boundary between the furrows and the xylem is in the form of a straight line in some species, but exhibits a structure more like a series of steps in others (Fig. 237 A and B). Phloem wedges of the simple type with straight radial edges present in species of *Arrabidaea*, *Callichlamys*, *Paragonia* and with the step-like edges in *Adenocalymma*, *Cuspidaria*, *Distictella*, *Fridericia*, *Petastoma*, *Pleonotoma*, *Stizophyllum*, *Tanaecium*, *Tynnanthus*. Another modification of the wedge type of anomalous structure is the development, as seen in transverse sections, of 4 radial groups of phloem united by medullary ray tissue. This type of structure is stated to occur particularly in *Bignonia phaseoloides* Cham., in species of *Distictella*, and possibly in *Haplolophium*.

II. *Secondary zones of growth in the cortex*

In species showing this anomaly, furrows are first formed as in I above, but new strands of xylem and phloem subsequently arise in the secondary cortex or pericycle and grow in thickness by means of cambial tissue between the xylem and phloem. This type of structure has been recorded particularly in *Callichlamys*, *Glaziova*, *Haplolophium*, and to a less extent in *Distictella* and *Doxantha*.

III. *Fissured xylem* (Fig. 237 C)

This type of structure is to be seen only in fairly old stems. Wedges of phloem are first formed, but the xylem mass subsequently becomes fissured by dilation and cell division in the pith and in the parenchyma of the wood.

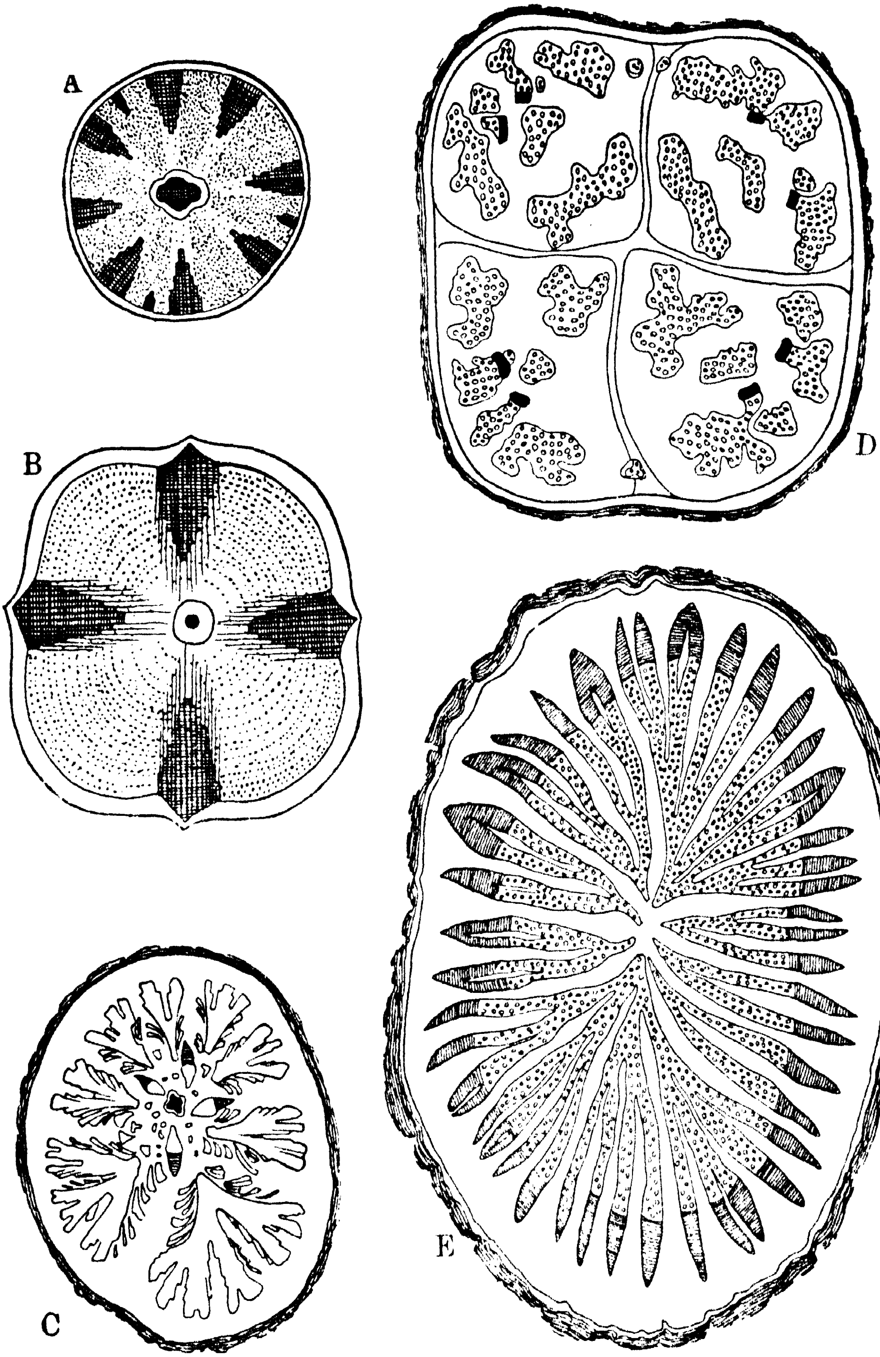


FIG. 237. *BIGNONIACEAE*, A–C; *ACANTHACEAE*, D; *ARISTOLOCHIACEAE*, E
Anomalous xylem. A, *Bignonia aequinoctialis* Linn. × 1½. B, No. 633 in H. Schenck's collection of Woods, nat. size. C, *Bignonia* sp. No. 137 in H. Schenck's collection of woods. D, *Mendoncia velloziana* Nees. × 3. E, Anomalous axis of *Aristolochia triangularis* Cham.—A, by Solereder, B–E, after H. Schenck.

This type is stated to occur in *Bignonia*, *Doxantha*, *Macfadyena*, *Melloa*, *Parabignonia*.

IV. Arcs of inversely orientated bundles at the margin of the pith reported or observed in species of *Campsis* (Handa 883), *Clytostoma*, *Tecoma*, *Tecomaria*.

Solereder, pp. 608–10, gives a key to numerous genera of Bignoniaceae, based largely on differences in the anomalous thickening. As material has not been available to check the accuracy of the key, it has not been reprinted in the present book. It should, however, be taken into consideration when the subject is reinvestigated.

Economic Uses

Tabebuia, in the sense used by Bentham and Hooker, is the source of several important timbers. Record and Hess (1886) distinguish 3 main groups. (1) White Cedar, *T. insignis* (Miq.) Sandw., which is a non-durable wood, useful for the same general purposes as Birch; (2) Roble, *T. pentaphylla* (L.) Hemsl. and other species, used for ox-yokes, house construction, boat-building and piling, and also for flooring and interior finish, and (3) Lapacho, *T. ipe* (Mart.) Standl. and several other species, which includes several strong, heavy, and durable timbers. Two other important timbers, both of which have at some time been regarded as species of *Tabebuia*, are Peroba or Ipe Peroba, *Paratecoma peroba* (Record) Kuhlm., which is one of the most important woods in Rio de Janeiro for internal finish and first-class cabinet work, and Primavera, *Cybistax donnell-smithii* (Rose) Siebert, which is a yellow wood used for cabinet work and veneers. Pearson and Brown (1679) note 3 Indian genera as producing timber of secondary importance; the most important of these is *Stereospermum*.

Calabashes are the shells of the fruits of *Crescentia cujete* Linn. Members of the genus *Kigelia* are known as Sausage Trees on account of the shape of the fruits, which are sometimes used by the natives in West Africa for medicinal purposes. A number of representatives of this family are cultivated for decorative purposes in countries which are sufficiently warm, and a few are hardy in Britain.

Genera Described

(i) For General Anatomy

Adenocalymma, Amphicome, Amphilophium, Anemopaegma, Arrabidaea, Bignonia, Callichlamys, Campsis,* Catalpa,* Chilopsis, Clytostoma,* Colea, Cremastus, Crescentia,* Cuspidaria, Cydista, Distictella, Dolichandrone, Doxantha, Eccremocarpus,* Fridericia, Glaziova, Haplolophium, Incarvillea,* Jacaranda, Kigelia,* Lundia, Macfadyena, Melloa, Oroxylon, Pandorea, Parabignonia, Paragonia, Parmentiera,* Petastoma, Phryganocydia, Phyllarthron, Pithecoctenium, Pleonotoma, Pyrostegia, Schlegelia, Spathodea, Stizophyllum, Tabebuia,* Tanaecium, Tecomaria,* Tynanthus, Zeyheria.

* Represented in the Kew slide collection.

(ii) For Wood Structure

Adenocalymma, Anemopaegma, Arrabidaea, (Astianthus), (Bignonia), Callichlamys, Campsis, Catalpa, Chilopsis, Cotema, Couralia, Crescentia, Cydista, Deplanchea, Diplanthera, Distictella, Dolichandrone, Ekmanianthe,

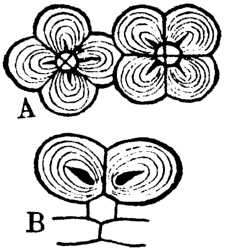
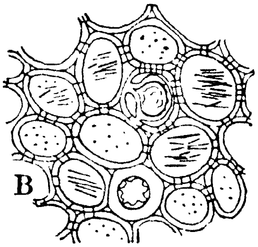


FIG. 238. *PEDALIACEAE*
Mucilage-hair of *Sesamum indicum* L.—Solereder.



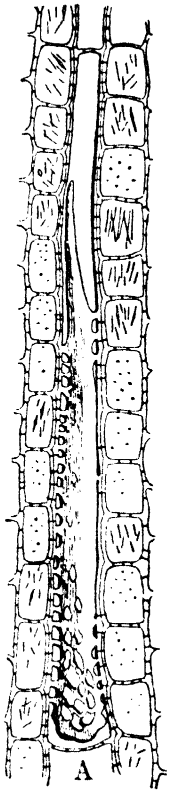


FIG. 239. *ACANTHACEAE*
Cystoliths in the pith of '*Goldfussia isophylla* Nees'. A, Longitudinal section of the pith with a lithocyst. B, Transverse section through the pith with two lithocysts cut transversely; there are also small acicular crystals in the cells of the pith.—Solereder.

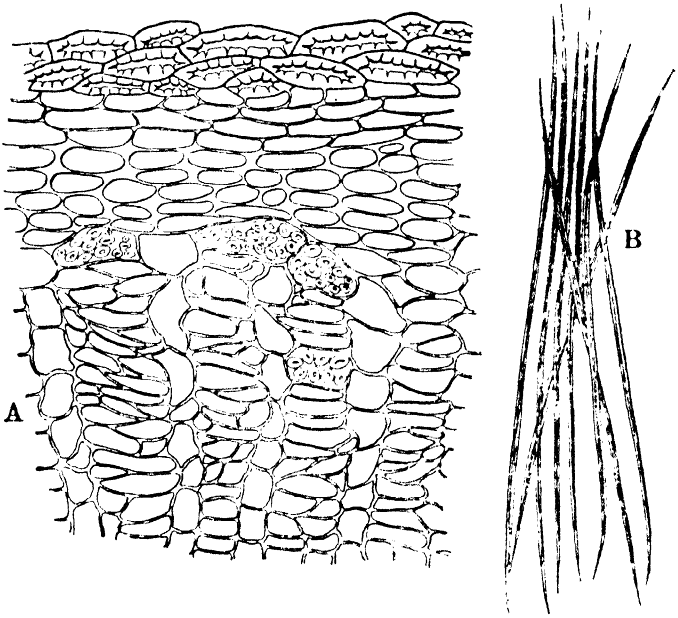


FIG. 240. *ACANTHACEAE*
Acicular fibres of the Acanthaceae: A, Transverse section through the inner portion of the cortex (pericycle and phloem) in '*Adhatoda ventricosa* Nees', showing the bundles of acicular fibres in transverse section; B, Group of acicular fibres from the leaf of [illegible]

Enallagma, Godmania, Heterophragma, Jacaranda, Kigelia, Macrodiscus, Markhamia, Martinella, Mayodendron, Melloa, Memora, Millingtonia, Newbouldia, Oroxylon, Pajanelia, Paratecoma, Parmentiera, Petastoma, Pithecoctenium, Potamoganos, Radermachera, Schlegelia, Spathodea, Stenolobium, Stereospermum, Tabebuia, Tecoma, (Tecomaria).

LITERATURE

(i) *On General Anatomy*

Handa **883**, Pfeiffer, H. **1710**, Rao **1773**, Scott, F. M. **2070**, Shirley and Lambert **2089**.

(ii) *On Wood Structure*

Bastos **147**, Becking *et al.* **164**, Benoist **170**, den Berger **179**, Bournot **246**, B.H. For. Dept. **274**, Brown, H. P. and Panshin **288**, Burgerstein **312**, Chalk **352**, Desch **574**, Giordano **786**, Gonggrijp **794**, Greguss **2522**, Howard **1088**, Isenberg **1124**, Janssonius **1147**, **1154**, Kanehira **1206**, **1209**, Lecomte **1334**, Martin-Levigne **1450**, Panshin **1649**, Pearson and Brown **1679**, Pereira **1687**, Pfeiffer, H. **1710**, **1711**, **1712**, Pfeiffer, J. Ph. **1713**, Record **1781**, **1783**, **1797**, **1809**, **1843**, **1851**, Record and Hess **1886**, **1888**, Record and Mell **1894**, Seibert **2078A**, Stone **2202**, **2207**, Tang **2230**, Thompson **2254**, Williams **2430**, Yamabayashi **2478**.

204. PEDALIACEAE

(FIG. 238 on p. 1012; FIG. 244 on p. 1026)

SUMMARY

A family of herbs, from warm regions especially in Africa. The family is characterized by mucilage **hairs,** with heads composed of 4 or more cells convexly arched towards the exterior (Fig. 238). These hairs are very widely distributed and probably occur in all species. The leaf is usually dorsiventral and provided with **stomata** on both surfaces, although exceptions occur. No other particularly noteworthy features have been recorded.

LEAF

Usually dorsiventral. Capitate, short-stalked, mucilage **hairs** (Fig. 238 A–B) probably occur in all species; sometimes appearing as numerous white grains on the lower surface of the leaf. The heads of these hairs consist of 4 or more cells, the latter being convexly arched outwards from the apex of the hairs, and the lumina almost completely filled with mucilage. Hairs with long or short unicellular or uniseriate stalks and spherical or turbinate heads composed of cells arranged in a palisade-like manner, also recorded in *Ceratotheca*, *Martynia*, *Sesamum*. Long, uniseriate, non-glandular trichomes composed of cells with wide lumina occur in species of *Ceratotheca*, *Craniolaria*, *Martynia*, *Sesamum*; 1- or 2-celled hairs with verrucose surfaces present in *Rogeria*. **Stomata** ranunculaceous; present on both surfaces of the leaf in most of the investigated species of *Martynia*, *Pedalium*, *Rogeria*, *Sesamum*, and other genera; confined to the lower side in *Craniolaria annua* Linn.; absent from submerged leaves of *Trapella sinensis* Oliv., but present on the upper surface of floating leaves of the same species. **Hydathodes,** situated at the terminations of veins, occur in the indentations of the leaf margin in *Trapella*. **Petiole** (Fig. 244 B) of *Martynia fragans* Lindl. examined at Kew, exhibiting, in transverse sections through the distal end, a sinuously crescentic vascular strand, with small accessory bundles on the adaxial side between the ends of the crescent, and others in the cortical region on either side of the adaxial groove. **Crystals,** when present, always small and either solitary or clustered, the former type said by Solereder to be particularly numerous in the mesophyll of *Martynia diandra* Glox. and *Rogeria adenophylla* Gay.

AXIS

YOUNG STEM (Fig. 244 E)

Cork arising in the sub-epidermis in *Pedalium* sp. Primary **cortex** somewhat spongy in *Martynia fragrans* Lindl. **Pericycle** containing strands of fibres in *Sesamum indicum* Linn. or of fibres and stone cells in *Rogeria adenophylla* Gay. Pericyclic sclerenchyma absent from species of *Pedalium.* **Xylem** described by Solereder as dissected by narrow, or locally by broader, rays; vessels up to about 60 μ in diameter and provided with simple perforations; wood fibres with relatively wide lumina and simple pits. Xylem of *Martynia fragrans* Lindl. (Fig. 244 E), when examined at Kew, seen to conform with the above description; vessels rather irregularly distributed and exhibiting a wide range of size, the largest being about 60 μ in radial diameter, and those of the protoxylem minute and arranged in radial rows. Lateral pitting of the vessels in the same species tending to be horizontally elongated. **Pith** sometimes septate in *Pedalium*; somewhat lacunar and becoming hollow in *Martynia fragrans.* **Crystals** resembling raphides recorded in the pith of *Rogeria.*

ECONOMIC USES

Sesamum oil, used in soap-making and for culinary purposes, &c., is derived from the seeds of *Sesamum indicum* Linn., which is cultivated in India and other warm countries. The hooked fruits of some members of this family become easily entangled with the coats of animals and may cause serious distress.

GENERA DESCRIBED

Ceratotheca, Craniolaria, Martynia,* Pedalium, Rogeria, Sesamum, Trapella.

* Represented in the Kew slide collection.

LITERATURE

On General Anatomy

Sayeedud-Din **2003**.

205. ACANTHACEAE

(FIG. 237 on p. 1010; FIG. 239 on p. 1012; FIG. 240 on p. 1012; FIG. 241 on p. 1016; FIG. 242 on p. 1018; FIG. 243 on p. 1020)

SUMMARY

(i) GENERAL

This family, which occurs chiefly in hot countries, is mainly herbaceous, but some of its members are climbers or lianes, whilst a few species are woody. It also includes xeromorphic species with spiny leaves. The spines at the nodes of *Hygrophila spinosa* T. Anders. have been shown by Kundu (1303) to be modified branches. The variation in the structure of the pollen grains provides a feature of diagnostic value. One of the most outstanding anatomical features is the widespread occurrence of variously shaped **cystoliths,** which are to be found in both stem and leaf. **Anomalous secondary thickening,** including the occurrence of **intraxylary** and **interxylary phloem,** has also been recorded in a number of genera. The **hairs** comprise an assortment of both glandular and non-glandular types. The **mesophyll** is usually partly or wholly dorsiventral, although isobilateral structure has been reported. **Stomata,** which occur on both surfaces or are confined to the lower side, are always caryophyllaceous. Bundles of bodies which are usually described as **acicular fibres,** but which resemble large raphides, occur in certain species and are stated to be peculiar to this family. Calcium oxalate **crystals** are secreted in the form of prisms, needles, and in other shapes. No particularly characteristic features are known in the young stem apart from the anomalous structure mentioned above.

(ii) WOOD

Vessels very small, occasionally with a radial pattern, perforations simple, intervascular pitting alternate and minute, pits to parenchyma usually similar, sometimes elongated, members of medium length. **Parenchyma** scanty paratracheal or vasicentric, sparse. **Rays** 1–6 cells wide, often high, typically composed exclusively of square or upright cells. **Fibres** septate and with simple pits; of medium length to moderately short.

LEAF

Usually partly or wholly dorsiventral in the rather incomplete material so far examined, but isobilateral structure reported by Solereder, for example in species of *Acanthopsis* and *Lepidagathis*, and by Sabnis (1977) in a few species of *Barleria*, *Blepharis*, *Justicia*, *Ruellia*. **Hairs** include non-glandular and secretory types, the former mostly unicellular or uniseriate.

A. Non-glandular hairs. The Barlerieae are characterized particularly by unicellular hairs with thick walls and narrow lumina, the latter being enlarged towards the base of each hair. The Aphelandreae, with the exception of *Stenandrium*, have long uniseriate hairs with strongly thickened walls. The Acantheae bear short unicellular or bicellular hairs with unthickened walls, but long, thin-walled, uniseriate trichomes also occur in this Tribe. Unicellular, 2-armed hairs recorded in *Barleria* (pro parte); candelabra hairs in a few species of *Barleria* and *Ruellia*; uni- or multicellular, lanceolate hairs in *Acanthopsis horrida* Nees.

B. Glandular hairs. Occurring generally throughout the family; mostly small with short stalks, but typically of the two main types shown in Fig. 241 B and D. Salt-secreting glands present on both surfaces, but most numerous on the upper side in *Acanthus ilicifolius* Linn. according to Mullan (1570).

Epidermis sometimes papillose in *Aphelandra* and *Ruellia*. Enlarged, convex, epidermal cells, each with a very small cell shaped like a biconvex lens at the apex, present in *Fittonia verschaffeltii* A. Coem. **Stomata** present on both surfaces in some species, but confined to the lower side in others; nearly always caryophyllaceous (Fig. 241 A), but said by Mullan (1571) to be

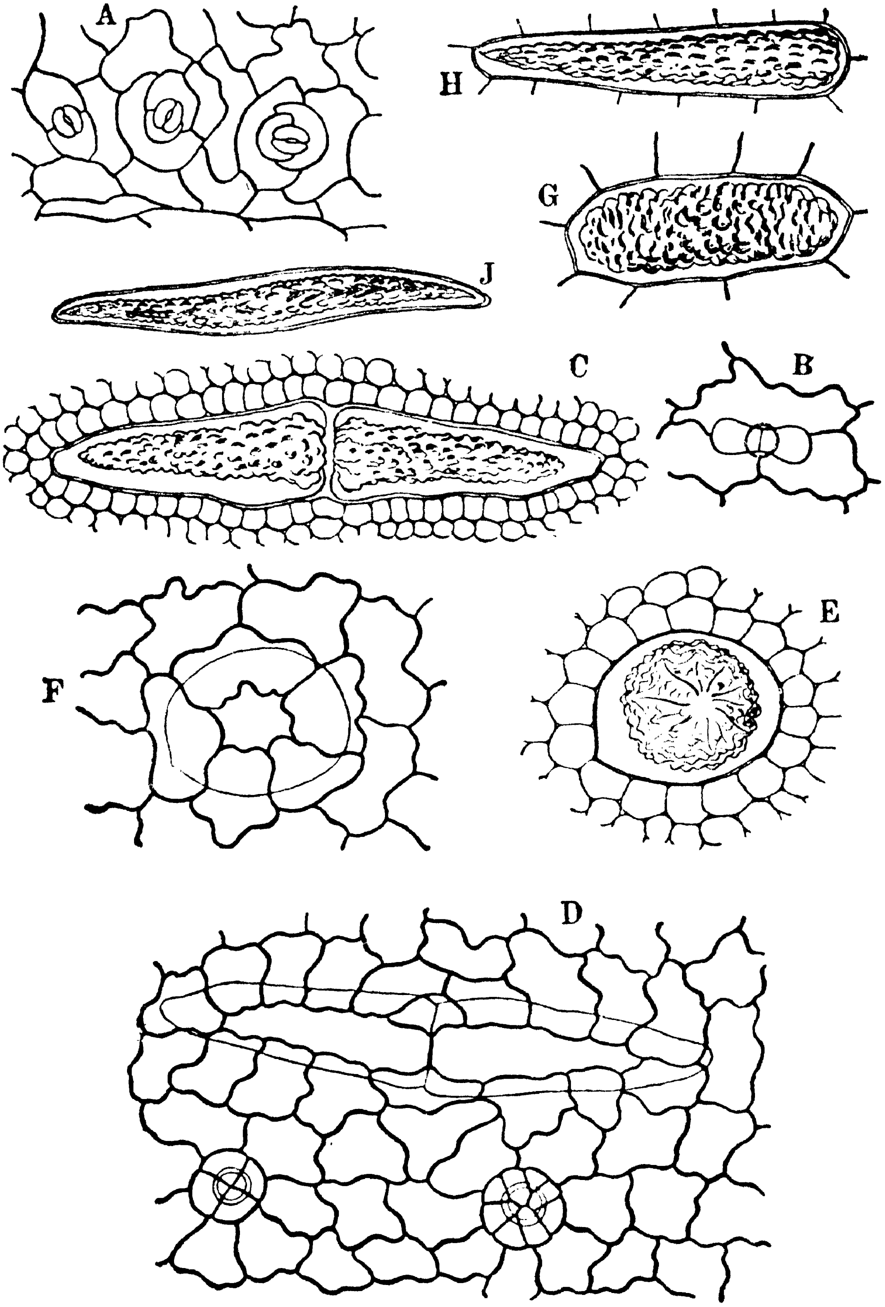


Fig. 241. *ACANTHACEAE*

A, Type of stoma found in the Acanthaceae. B, Glandular hair of *Thunbergia fragrans* Roxb. C, D, *Barleria prionitis* L.: C, Double cystoliths with the cells containing them, and the surrounding palisade-tissue seen from the surface at a low focus; D, Portion of the epidermis of the leaf of the same plant, the cystoliths being omitted. E–F, *Asystasia scandens* Hook.: E, Cystolith with the cell containing it, as in C; F, Portion of the upper epidermis of the leaf with a lithocyst, as in D. G, Cystolith of *Justicia ecobolium* L. H, Cystolith of *Ruellia* sp. J, Cystolith of *Sanchezia* sp.—By Solereder.

rubiaceous in *Lepidagathis trinervis* Nees. **Hypoderm** recorded towards the upper surface in *Acanthus ilicifolius* and on the lower side in *Blepharis sindica* T. Anders.

Statements by Solereder, and examination of material at Kew, indicate that the **petiole** (Fig. 242 A–D and F), in transverse sections through the distal end, exhibits a single arc-shaped vascular strand or a crescentic group of separate bundles in species of *Aphelandra*, *Asystasia*, *Barleria* (Fig. 242 A), *Beloperone*, *Daedalacanthus* (Fig. 242 C), *Eranthemum*, *Fittonia*, *Jacobinia*, *Peristrophe*, *Ruellia*, *Sanchezia* (ends of the crescent very much incurved in some species), *Schaueria*, *Strobilanthes*, *Thunbergia* (pro parte) (Fig. 242 F), *Whitfieldia*; a circle of more or less separate bundles present in the corresponding position in *Acanthus* (Fig. 242 B) and *Thunbergia* (pro parte) and a cylindrical vascular strand in *Crossandra* (Fig. 242 D). Three steles, each surrounded by an amyliferous endodermis, recorded by Mullan (1569) in the petiole of *Acanthus ilicifolius*. Subsidiary bundles usually present towards the adaxial surface or on either side of the petiolar groove.

Cystoliths (Figs. 239 A–B and 241 C–J), in the form of silicified bodies with a cellulose skeleton or occasionally not encrusted, occur in both axis and leaf of numerous species. Particulars concerning their development have been recorded by Linsbauer (1378). Their nature and distribution are valuable for the recognition of genera and species. A. Not always present in species of *Acanthus*, *Aphelandra*, *Blepharis*, *Crossandra*, *Ebermaiera*, *Elytraria*, *Geissomeria*, *Mendoncia*, *Meyenia*, *Nelsonia*, *Pseudocalyx*, *Stenandrium*, *Thunbergia*. B. Double cystoliths, sometimes accompanied by simple types (Fig. 241 C–D), recorded in species of *Barleria*, *Barleriola*, *Crabbea*, *Glossochilus*, *Lophostachys*, *Periblema*. C. Solitary, round cystoliths (Fig. 241 E–F) recorded in species of *Andrographis*, *Anthacanthus*, *Asystasia*, *Codonacanthus*, *Cystacanthus*, *Gymnostachyum*, *Haplanthus*, *Phlogacanthus*, *Pseuderanthemum*. D. Solitary, elongated cystoliths with blunt extremities (Fig. 241 G) present in species of *Adhatoda*, *Anisotes*, *Barleriola*, *Beloperone*, *Glockeria*, *Graptophyllum*, *Harpochilus*, *Isoglossa*, *Jacobinia*, *Justicia*, *Lepidagathis*, *Lophostachys*, *Monothecium*, *Rhinacanthus*, *Schaueria*, *Schwabea*, *Siphonoglossa*, *Thyrsacanthus*. E. Solitary, elongated cystoliths with one end pointed (Fig. 241 H) occur in *Blechum*, *Chaetothylax*, *Chamaeranthemum*, *Daedalacanthus*, *Echinacanthus*, *Habracanthus*, *Herpetacanthus*, *Jacobinia*, *Neuracanthus*, *Pentstemonacanthus*, *Phaylopsis*, *Ruellia*, *Spirostigma*, *Trichanthera*. F. Similar to E but pointed at both ends in *Rostellaria* and *Sanchezia*. G. Cystoliths of variable shape present in numerous genera, particularly amongst the Dicliptereae and Ruellieae sensu Bentham and Hooker. Non-calcified, elongated, slightly lignified cystoliths recorded, particularly in the pith, in *Ruellia* and *Strobilanthes*. Cystoliths intermediate in character between the above categories also occur. Cystoliths and their immediate surroundings in species of *Goldfussia*, *Sanchezia*, and *Strobilanthes* sometimes pigmented when observed in damaged tissues, owing to a colourless substance assuming a blue-green colour when exposed to the air. The greenish colour of the cystoliths, sometimes visible in sections of *Ruellia ochroleuca* Mart., is said by Solereder, on the other hand, to be due to the anthocyanin in the surrounding cells changing to green owing to the alkaline reaction of the cystoliths. The mode of development of cystoliths by the aggregation of

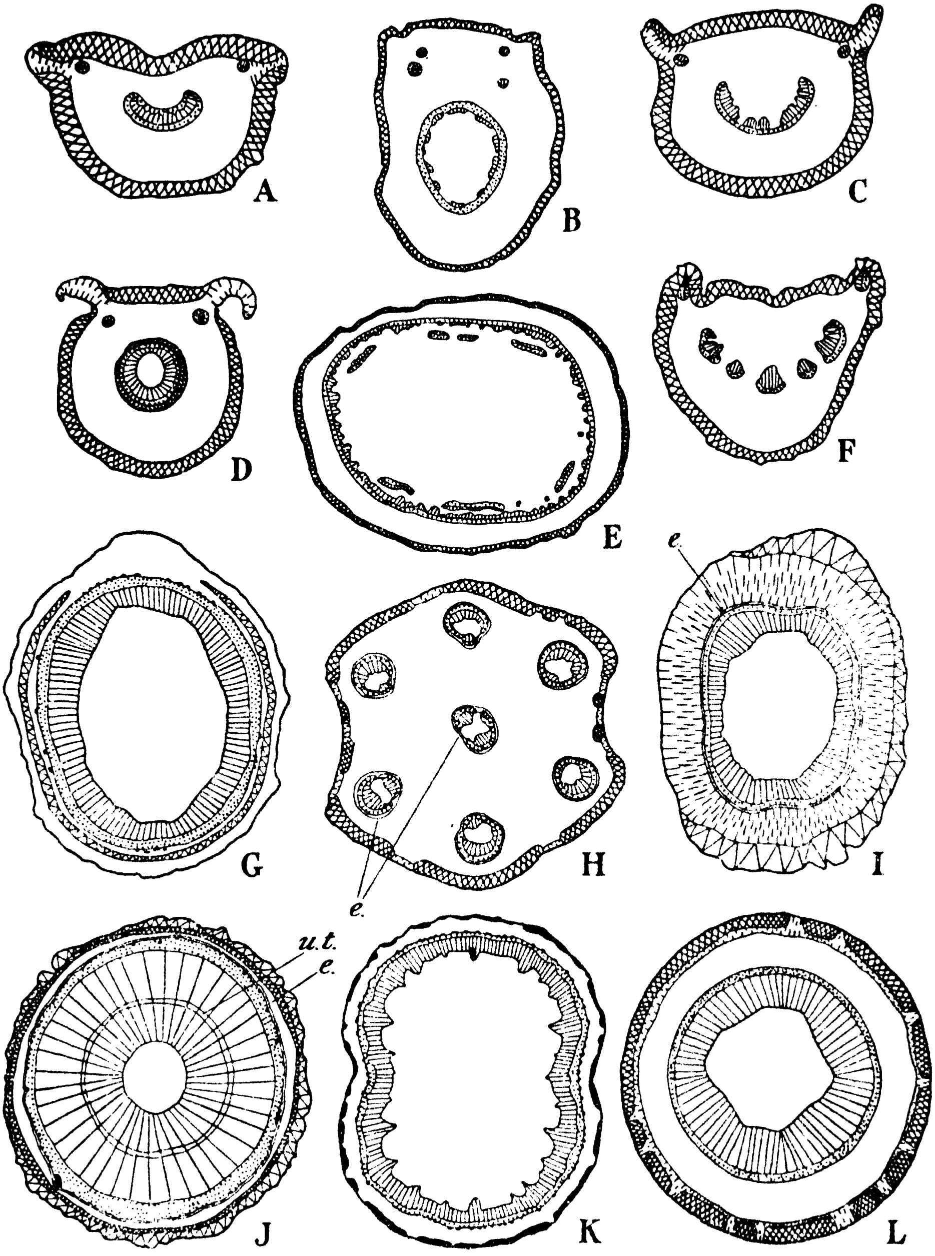


FIG. 242. *ACANTHACEAE*

A, *Barleria lanceifolia* T. Anders. Petiole × 62. B, *Acanthus mollis* Linn. Petiole × 15. C, *Daedalacanthus nervosus* T. Anders. Petiole × 38. D, *Crossandra undulaefolia* Salisb. Petiole × 42. E, *Acanthus mollis* Linn. Stem × 19. F, *Thunbergia natalensis* Hook. Petiole × 40. G, *Asystasia bella* Benth. Stem × 36. H, *Dianthera americana* Linn. Stem × 36. I, *Barleria lanceifolia* T. Anders. Stem × 50. J, *Dianthera nodosa* Benth. Stem × 23. K, *Thunbergia natalensis* Hook. Stem × 25. L, *Crossandra undulaefolia* Salisb. Stem × 42.

e. Endodermis. *u.t.* Zone of unlignified ground tissue.

In Figs. C, F, and K the numerous acicular crystals are not shown. In Fig. G there are a few cystoliths in the peripheral tissue. In Fig. I small strands of intraxylary phloem are not shown. In Fig. J there are occasional cystoliths in the cork.

minute crystals in vacuolated cells near the stem apex of *Beloperone* and other genera has recently been described by Scott (2073).

Bundles of **acicular fibres** (Fig. 240 A–B) varying in abundance, resembling very large raphides, and said to be peculiar to the family, sometimes present in the phloem of the axis as well as in the veins and petiole of the leaf. Details of their occurrence not well known, but recorded in species of *Acanthopsis*, *Adhatoda*, *Andrographis*, *Anisacanthus*, *Aphelandra* (root), *Barleria*, *Crossandra*, *Cystacanthus*, *Dianthera*, *Dicliptera*, *Ecbolium*, *Eranthemum*, *Fittonia*, *Jacobinia*, *Justicia*, *Mendoncia*, *Peristrophe*, *Pseudocalyx*, *Rhinacanthus*, *Ruellia*, *Sanchezia*, *Sautiera*, *Thunbergia*. **Crystals** of calcium oxalate, in the form of prisms, raphides, and in other shapes, secreted in the mesophyll or epidermis (*Aphelandra*, *Ruellia*) of the leaf, but often present in the parenchymatous tissues of the axis as well. Abundant, small, prismatic crystals present throughout the mesophyll of *Andrographis echioides* Nees. according to Sayeedud-Din (2005). **Oil** recorded in the palisade cells of *Acanthus ilicifolius*.

AXIS

YOUNG STEM (Fig. 242 E and G–L)

Quadrangular in *Lepidagathis trinervis* Nees. according to Mullan (1571), the distal ends of the wings being collenchymatous and the proximal region chlorenchymatous. **Epidermis** consisting of 2–3 layers of cells in species of *Barleria*, *Beloperone*, *Dianthera*, *Sanchezia*, *Strobilanthes*. A fibrous **hypoderm** present in nearly all species of *Thunbergia* and, less frequently, in *Mendoncia*. Variations in the structure of the hypoderm said to be valuable for the identification of species. **Cork** arising in or immediately below the epidermis in species of *Barleria* (Fig. 242 I), *Crossandra*, *Dianthera* (Fig. 242 J), *Eranthemum*, *Jacobinia*, *Ruellia*, *Strobilanthes*, *Thunbergia*, *Whitfieldia*; originating more deeply in the cortex in *Asystasia* (Fig. 242 G) and, according to Solereder, in the endodermis in *Phaylopsis*. Outer part of the primary **cortex** including fibres or fibrous cells in species of *Eranthemum*, *Nelsonia*, *Thunbergia* (Fig. 242 K), and *Thyrsacanthus*. Stone cells recorded in the inner part of the cortex in a few species of *Dianthera*, *Jacobinia*, *Justicia*, *Strobilanthes*, *Thunbergia*. Transverse sections through the outer part of the cortex, in the very young stem of most of the species examined at Kew, exhibiting alternating sectors of collenchyma and chlorenchyma respectively (Fig. 242 H, L). Cortex very lacunar in the halophytic *Acanthus ilicifolius* Linn. according to Mullan (1569) and in *Hygrophila* according to Solereder, the component cells of the walls of the meshes in *H. spinosa* T. Anders. described as resembling a series of interlocking thigh-bones when viewed in transverse sections. A conspicuous **endodermis** recorded in species of *Andrographis*, *Barleria*, and *Thunbergia*. Casparian thickenings noted at Kew in species of *Asystasia*, *Dianthera*, *Eranthemum*, *Jacobinia*, *Sanchezia*, *Strobilanthes*, *Whitfieldia*. **Pericycle** usually including strands of fibres, or, less frequently, devoid of sclerenchyma, e.g. in species of *Barleria*, *Jacobinia*, *Justicia*, *Peristrophe*; a composite and continuous ring of sclerenchyma recorded in *Mendoncia*. **Phloem** seen to include fibres in species of *Asystasia*, *Crossandra*, *Daedalacanthus*, *Eranthemum*, *Ruellia*, *Sanchezia*, *Whitfieldia*.

Xylem, in all of the species examined at Kew except *Dianthera americana* Linn. (Fig. 242 H), forming a closed cylinder traversed by narrow rays, but broad sectors of the xylem ring are devoid of vessels in *Peristrophe speciosa* Nees. and *Thunbergia natalensis* Hook. (Fig. 242 K). Vessels usually evenly distributed, but commonly tending to be in radial rows. Vessels in *T. natalensis* up to about 80 μ in radial diameter, thus being considerably larger than those in young stems of most members of the family. Vessels with simple perforations.

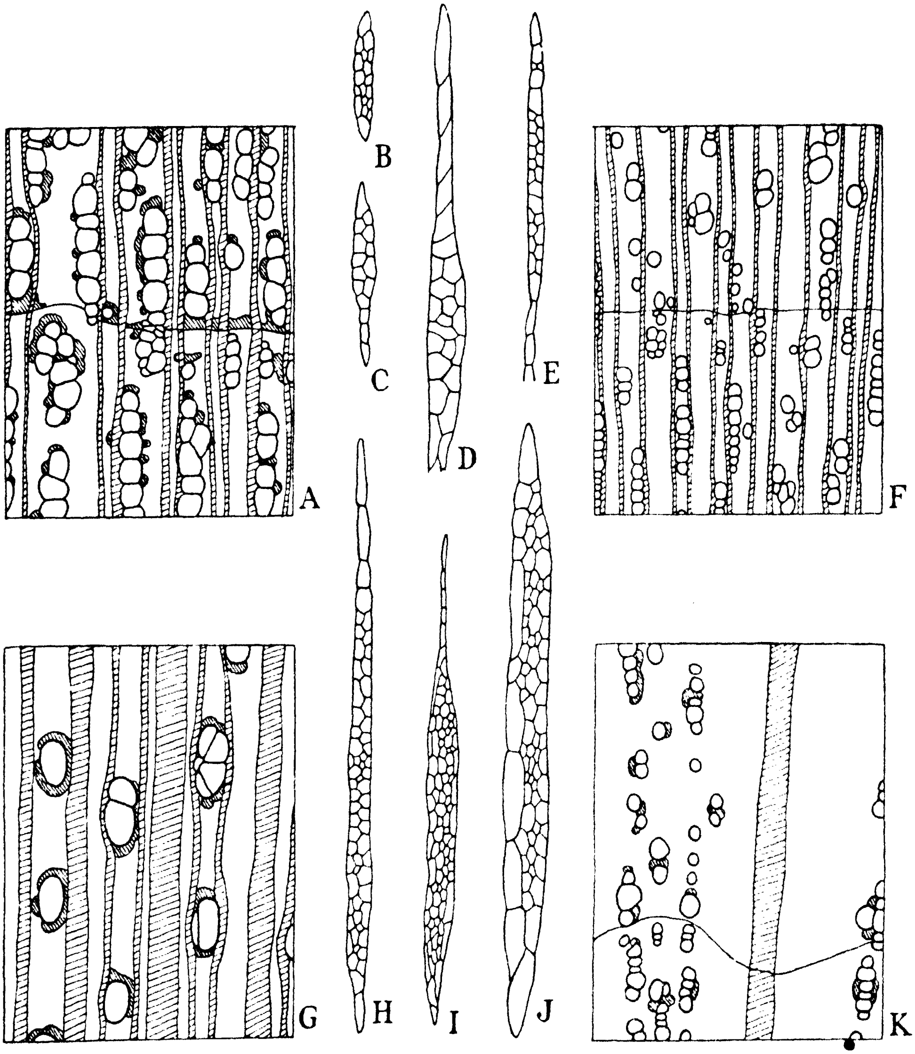


FIG. 243. *MYOPORACEAE*, A–C; *ACANTHACEAE*, D–K

A, *Eremophila bignoniflora* F. v. Müll. B, *Myoporum platycarpum* R. Br. C, *Eremophila mitchelli* Benth. D, *Whitfieldia colorata* C. B. Clarke. E, *Pseudoblepharis glischrocalyx* Mildbr. F, *Beloperone braceteosa* Mildbr. G, *Sanchezia williamsii* Leonard. H, *Eranthemum insolanum* A. Gray. I, *Anisacanthus thurberi* A. Gray. J, *Bravaisia integerrima* Standley. K, *Isoglossa* sp.

Four groups of collateral and inversely orientated **medullary bundles** recorded in species of *Acanthus*, and similar bundles accompanied by anomalous structure in species of *Mendoncia* (Niesemann 1601) and *Pseudocalyx*. Isolated, thick-walled vessels recorded by Sabnis (1977) in the pith of *Barleria hochstetteri* Nees. Inconspicuous groups of **intraxylary phloem** recorded or noted in species of *Acanthus*, *Barleria* (probably present throughout this genus), *Glossochilus*, *Lepidagathis*, *Lophostachys*, *Nelsonia*, *Neuracanthus*, *Somalia*, and *Volkensiophyton*.

Vascular system of *Dianthera americana* Linn. (Fig. 242 H) observed at Kew to consist of 7 distinct steles, each centric in structure and surrounded by an endodermis with casparian thickenings. Six of the steles arranged symmetrically around the circumference of the stem, the remaining solitary one being central.

The **developmental anatomy** of *D. americana* has been studied by Jones (1190), according to whose account the seedling is at first monostelic. Interfascicular cambium does not develop between the 4 original bundles in the seedling, but each becomes surrounded by an endodermal sheath. Two additional bundles in the mature axis are formed in association with the enlarged leaf gaps. The peripheral meristeles and the one central bundle anastomose at the nodes. The inflorescence axis is monostelic. *D. americana* differs from related species in the lack of interfascicular cambium. Its medullary bundle is comparable to those of *Acanthus spinosus* Linn., many Campanulaceae, and other plants. Jones suggests that the peculiar structure of *D. americana* is correlated with the aquatic habitat of this species.

Pith generally occupying a large part of the centre of the stem. For the occurrence of **cystoliths, acicular fibres** (Fig. 240 A–B), and **crystals** see also under 'Leaf'. Raphides or very small spindle-shaped crystals noted at Kew in the cortex and pith of species of *Barleria*, *Crossandra*, *Eranthemum*, and *Thunbergia*, in the pith of *Asystasia* and *Daedalacanthus*, and in the phloem and pith of *Sanchezia*. Solitary and acicular crystals in the cortex of *Acanthus ilicifolius* and rod-shaped crystals in the cortex and pith of *Lepidagathis trinervis* Nees. recorded by Mullan (1571). Small, prismatic crystals noted by Sayeedud-Din (2005) in the primary cortex and pith of *Andrographis echioides* Nees. Observations made at Kew on the distribution of cystoliths in the axis of representatives of a few genera indicate the probable generic and specific diagnostic value of these structures, but they need further critical investigation. Cystoliths confined to the epidermal layers in species of *Asystasia*, *Barleria*, *Beloperone*, *Dianthera*, *Jacobinia*, *Ruellia*, present in the epidermis, cortex, phloem, and pith of species of *Strobilanthes*, recorded in the phloem and pith but said to be absent from the epidermis in *Daedalacanthus* and *Sanchezia*.

WOOD (Fig. 243 D–K)

Vessels typically very small (less than 50 μ mean tangential diameter) and sometimes extremely small (less than 25 μ), e.g. in *Whitfieldia colorata* C. B. Clarke, but slightly larger in *Sanchezia* and medium-sized (100–200 μ) in *Bravaisia integerrima* (Spreng.) Standl. and *Tricanthera* (1886); with some multiples of 4 or more cells and a tendency for these and the solitary vessels to be grouped in radial rows in *Beloperone*, *Isoglossa* (Fig. 243 F and K), and *Pseuderanthemum*, and, according to Record and Hess (1886), in *Appelandra* and *Pachystachys riedeliana* Nees.; 3 to over 100 per sq. mm., fewest (about 3 per sq. mm.) in

Bravaisia integerrima, 20–40 per sq. mm. in some species of *Eranthemum*, *Graptophyllum*, *Pachystachys*, *Pseudoblepharis*, and *Whitfieldia*, more than 40 per sq. mm. in the other genera examined; semi-ring-porous and with fine spiral thickening in *Anisacanthus* and tending locally to be ring-porous in *Beloperone* (1886). Perforations simple, often with wide rims. Intervascular pitting alternate, minute; pits to ray and wood parenchyma similar, except in *Bravaisia*, *Sanchezia*, and *Tricanthera*, in which there are some larger, elongated pits. Thin-walled tyloses recorded (1886) in *Pachystachys*. Mean member length 0·4–0·6 mm. **Parenchyma** sparse, paratracheal, limited to narrow sheaths (Fig. 243 G) or a few cells round the vessels (Fig. 243 K); according to Hess (961) occasionally diffuse or terminal in *Anisacanthus*. Strands usually of 2 or 4 cells. **Rays** sometimes of 2 sizes, usually up to 2–4 cells wide, exclusively uniseriate in *Beloperone*, up to 5 or 6 cells in some species of *Bravaisia*, *Isoglossa*, *Pachystachys* (2430), and *Whitfieldia*; multiseriate rays typically up to more than 1 mm. high, but lower in some species of *Aphelandra*, *Bravaisia*, *Himantochilus*, *Pseudoblepharis*, and *Trichanthera*; uniseriate rays moderately numerous, sometimes low, usually composed entirely of high upright cells, but sometimes of mixed square and upright cells; 4–20 rays per mm., rather few in *Trichanthera*, most numerous in *Aphelandra*, *Barleria*, *Beloperone*, *Eranthemum*, and *Graptophyllum*; markedly heterogeneous and typically composed of square and upright cells with few or no procumbent cells; with 2 to several marginal rows of upright cells; sheath cells sometimes present. **Fibres** septate except in *Aphelandra*, *Pachystachys*, and *Pseudoblepharis*; with small, simple pits more numerous on the radial than on the tangential walls. Walls typically thin, but occasionally thick, e.g. in *Aphelandra*. Mean length 0·8–1·3 mm.

ANOMALOUS STRUCTURE

Besides the intraxylary phloem and the medullary bundles mentioned above under 'Young Stem', the 2 following anomalies have been reported. (i) Strands of intraxylary phloem in species of *Barleria*, *Glossochilus*, *Lepidagathis*, *Lophostachys*, *Neuracanthus*, *Somalia*, *Thunbergia* (for details concerning the different species see Solereder), *Volkensiophyton*. (ii) Fissured xylem in species of *Mendoncia* and *Thunbergia*. The peculiar vascular structure of *Dianthera americana* Linn. is also described above on p. 1021.

ROOT

The root system of *Acanthus ilicifolius* Linn., a mangrove plant, is morphologically similar to that of *Rhizophora* (Family Rhizophoraceae, see p. 609). The morphology and microscopical structure have been described by Liebau (1368) and Mullan (1569). The portion of the root system above the ground is well provided with lenticels and devoid of lateral branches, the subterranean part being branched. The pith and primary cortex consists of spongy tissue with well-developed intercellular spaces, some of the cortical cells being supported by thickening plates perforated by elongated pits. The cortical lacunae are less well developed in the aerial than in the subterranean parts of the root. The xylem is less well developed in the subterranean than in the aerial part of the root. It consists of a cylinder composed mainly of wood fibres, traversed by rays 1–3 cells wide and including rather infrequent vessels. The cork consists of 12–15 layers of cells in the aerial part and of 5–8 layers below ground-level. Tannin and acicular crystals occur in the cortical parenchyma. Long root-hairs, intraxylary phloem, short sclerenchymatous cells in the cortex, and a pitted, lignified pith recorded by Mullan (1570) in *Neuracanthus* sp.

ECONOMIC USES

A blue dye is obtained in India from the leaves and stems of *Strobilanthes flaccidifolius* Nees., and a yellow dye from the leaves of *Adhatoda vasica* Nees. *Andrographis paniculata* Nees. possesses bitter properties resembling those of Gentian Root. It is used medicinally in India. The root of *Rhinacanthus communis* Nees. is used in India and China for the treatment of ringworm. Various members of the family are commonly cultivated for ornamental purposes.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Acanthopsis, Acanthus,* Adhatoda, Andrographis, Anisacanthus, Anisotes, Anthacanthus, Aphelandra, Asystasia,* Barleria,* Barleriola, Beloperone,* Blechum, Blepharis, Chaetocalyx, Chamaeranthemum, Codonacanthus, Crabbea, Crossandra,* Cystacanthus. Daedalacanthus,* Dianthera,* Dicliptera, Ebermaira, Ecbolium, Echinacanthus, Elytraria, Eranthemum,* Fittonia, Geissomeria, Glockeria, Glossochilus, Goldfussia, Graptophyllum, Gymnostachyum, Habracanthus, Haplanthus, Harpochilus, Herpetacanthus, Hygrophila, Isoglossa, Jacobinia,* Justicia, Lepidagathis, Lophostachys, Mendoncia, Meyenia, Nelsonia, Neuracanthus, Pentstemonacanthus, Periblema, Peristrophe,* Phaylopsis, Phlogacanthus, Pseuderanthemum, Pseudocalyx, Rhinacanthus, Rostellaria, Ruellia,* Sanchezia,* Sautiera, Schaueria, Schwabea, Siphonoglossa, Somalia, Spirostigma, Stenandrium, Strobilanthes,* Thunbergia,* Thyrsacanthus, Trichanthera, Volkensiophyton, Whitfieldia.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Anisacanthus, Aphelandra, Barleria, Beloperone, Bravaisia, Eranthemum, Graptophyllum, Himantochilus, Isoglossa, Pachystachys, Pseuderanthemum, Pseudoblepharis, Sanchezia, Trichanthera, Whitfieldia.

LITERATURE

(i) *On General Anatomy*

Dastur and Saxton **543**, Jones **1190**, Kundu **1303**, Liebau **1368**, Linsbauer **1378**, Mullan **1569**, **1570**, **1571**, Niesemann **1601**, Sabnis **1977**, Sayeedud-Din **2005**, Scott, F. M. **2073**, Zemke **2505**.

(ii) *On Wood Structure*

Hess **961**, Pfeiffer, H. **1712**, Record **1851**, Record and Hess **1886**, Williams **2426**, **2430**.

206. MYOPORACEAE

(FIG. 243 on p. 1020; FIG. 244 on p. 1026; FIG. 252 on p. 1054)

SUMMARY

(i) GENERAL

The trees and shrubs from Australia and Japan, &c., which constitute this family are characterized especially by **secretory cavities** lined with epithelium, which usually occur in the leaf and axis, although in some species they have been seen only in the axis. The **hairs** include glandular and non-glandular types, the secretory portion of the former being provided with vertical partitions only. In the leaf, the structure of the **mesophyll** is somewhat variable, but commonly isobilateral. **Stomata,** usually present on both surfaces, are cruciferous or ranunculaceous. The presence of **intraxylary phloem** in the young stem of *Oftia* serves to distinguish this genus from other members of the family.

(ii) WOOD

Vessels small, mostly in radial multiples and clusters and often with a radial, oblique, or tangential pattern, perforations simple, intervascular pitting alternate and minute, pits to parenchyma similar; members of medium length to moderately short. **Parenchyma** paratracheal, scanty, vasicentric or confluent, often storied. **Rays** typically 2–3 cells wide and low, heterogeneous, sometimes storied. **Fibres** with simple pits, of medium length to very short.

LEAF

Commonly isobilateral, but dorsiventral in species of *Oftia*. Leaves of the switch plant *Pholidia scoparia* R. Br. very much reduced. **Hairs.** Non-glandular trichomes either uniseriate, or branched and multicellular; both of these types recorded in species of *Eremophila*. Glandular hairs occur in all investigated species; each having a short or relatively long stalk of several cells, bearing a head with vertical partitions only (Fig. 252 A–C). Cells of the **epidermis** frequently papillose. Nearly all of the epidermal cells in *Eremophila alternifolia* R. Br. specialized for water storage. **Stomata** usually present on both surfaces, although confined to the lower side in *Oftia*; cruciferous in species of *Bontia*, *Eremophila* (pro parte), *Myoporum*, ranunculaceous in *Eremophila* (pro parte) and *Oftia*. **Midrib** embedded in the mesophyll in many members of the family, but surrounded by collenchyma in other species. Sclerenchyma usually poorly developed or absent around the vascular bundles of the veins but recorded in *Oftia*. **Petiole,** in transverse sections through the distal end of *Myoporum laetum* Forst. (Fig. 244 A) and *M. serratum* R. Br. examined at Kew, exhibiting a shallow, crescentic, median, vascular strand, accompanied by smaller accessory bundles on either side of the adaxial groove. **Secretory cavities** (see also under 'Axis'), lined with epithelium and usually secreting oily or resinous material, recorded or observed in the lamina and sometimes the petiole of all of the investigated genera except *Oftia*; when large, appearing as pellucid or raised dots. Oil glands recorded in *Pholidia* by Wood (2457). **Crystals** usually in the form of small clusters; particularly numerous in the mesophyll in certain species of *Eremophila* or in the mesophyll and epidermis in *Bontia*. Abundant acicular crystals recorded in *Eremophila drummondii* F. v. Müll., and clusters of yellow acicular crystals of unidentified material noted at Kew in the ground-tissue of the petiole of *Myoporum serratum*.

AXIS

YOUNG STEM (Fig. 244 D, I)

Surface of the switch plant *Pholidia scoparia* R. Br. described by Wood (2457) as covered with overlapping scales. **Cork** arising in the sub-epidermis. **Stomata** in species of *Oftia* said to be confined to the decurrent foliar wings. Primary **cortex** of several species of *Myoporum* containing wide intercellular spaces; seen to include a few isolated sclerosed cells in *M. serratum* R. Br. but not in *M. laetum* Forst.; outer part composed of palisade chlorenchyma and the inner portion of spongy parenchyma in the assimilatory stem of *Pholidia scoparia*. **Pericycle** containing small, isolated strands of fibres, e.g. in species of *Bontia*, or a loose ring of fibres and stone cells, e.g. in species of *Myoporum* (Fig. 244 D, I). Judging from species of *Myoporum* examined at Kew, separate strands of pericyclic fibres are first differentiated, the stone cells subsequently arising between them to form a loose ring in older stems. **Xylem** of *Myoporum* (Fig. 244 D, I) in the form of a continuous cylinder traversed by narrow rays. Vessels in short, well-defined, radial groups, the individual elements being up to about 45 μ in radial diameter in *M. laetum* and provided with simple perforations. Wood fibres in the same species consisting of elements with fairly wide lumina and conspicuously bordered pits. Small strands of **intraxylary phloem** stated to arise at a fairly late stage in *Oftia*. **Pith** somewhat heterogeneous in *M. laetum*, a proportion of the cells having thicker and somewhat more lignified walls than the remainder; homogeneous and composed of cells with fairly thick, pitted walls in *M. serratum*. **Secretory cavities** (see also under 'Leaf'), lined with epithelium, nearly always present in the primary cortex and/or pith of the axis except in *Oftia*. **Crystals,** usually in the form of small clusters, recorded in the primary cortex and pith. Variously shaped, mostly clustered crystals seen in the pith of *Myoporum laetum*; large solitary crystals reported to occur in the pericyclic stone cells of *Eremophila oldfieldii* F. v. Müll. and observed in the corresponding position in *Myoporum laetum*. Dense clusters of yellow acicular crystals of unidentified material noted in certain cells of the cortex and phloem, especially near the pericyclic sclerenchyma, in *M. serratum*. Disk-shaped crystalline bodies, soluble in hot water and in dilute acids, recorded in the pith of a number of species of *Myoporum*. Inulin said to occur in large quantities in the phloem parenchyma of the stem and in the cortex of the root in *Myoporum*.

WOOD (Fig. 243 A–C)

Vessels small (less than 100 μ mean tangential diameter), commonly in radial multiples of 4 or more cells and often in irregular clusters, the multiples tending to be of very many vessels near the centre of the stem; solitary vessels comparatively rare; often with a radial or oblique pattern and, less commonly, in loose tangential lines; 15–50 per sq. mm. Perforations simple. Intervascular pitting alternate, minute; pits to ray and wood parenchyma similar. Occasionally with solid contents. Brown (282) notes tyloses in *Myoporum* *sandwicensis* (DC.) A. Gray. Member length 0·2–0·4 mm. **Parenchyma** paratracheal, varying from a few cells to complete sheaths round the vessels; more abundant and confluent in *M. laetum* Forst. f. and *M. tenuifolium* Forst. and in narrow terminal bands in *Eremophila bignoniflora* F. v. Müll. Strands usually of 2, but often of 4, cells. Slightly to distinctly storied. **Rays** up to 2–3 cells wide: multiseriate rays low; uniseriate rays numerous, low, and composed of upright and procumbent cells; 10–18 rays per mm.; heterogeneous (Kribs's Type II B), with 1 or 2 marginal rows of square to upright cells; composed almost entirely of square to upright cells in *E. mitchelli* Benth. Sometimes containing crystals. Distinctly storied in *E. bignoniflora* and in echelon in *Myoporum platycarpum* R. Br. **Fibres** with numerous, small,

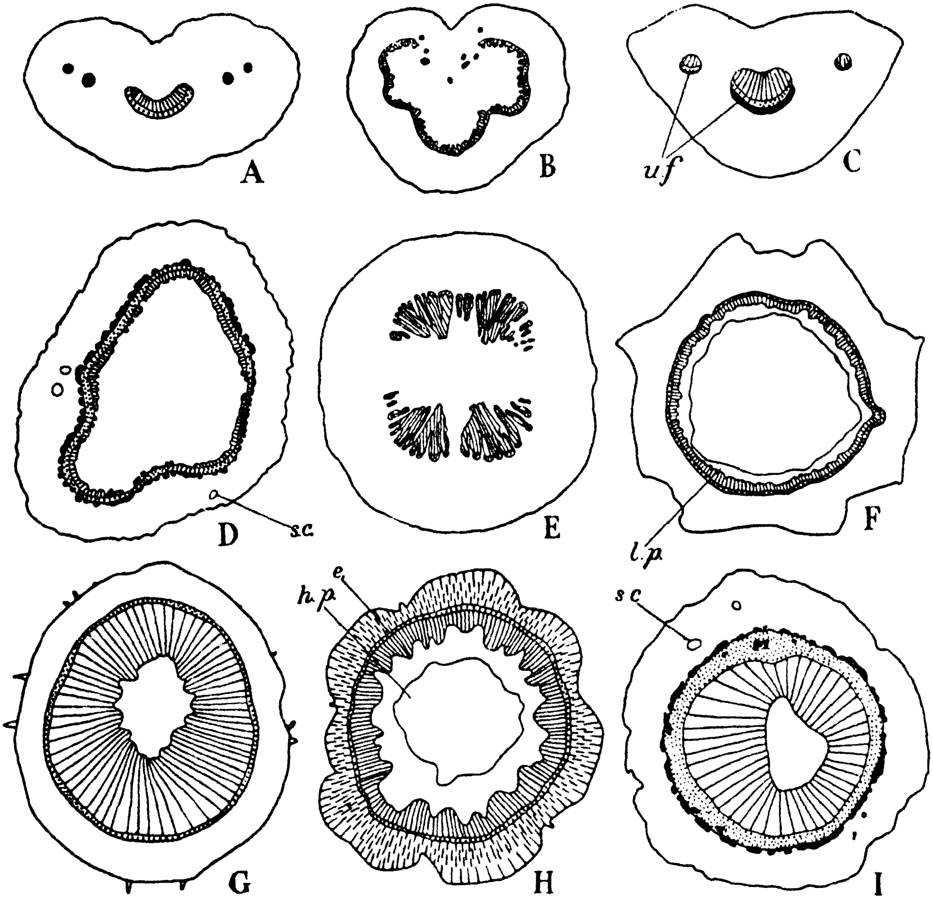


FIG. 244. *MYOPORACEAE*, A, D, and I; *PEDALIACEAE*, B and E; *GLOBULARIACEAE*, C and F; *SELAGINACEAE*, G–H

A, *Myoporum laetum* Forst. Petiole × 13. B, *Martynia fragrans* Lindl. Petiole × 8. C, *Globularia cordifolia* Linn. Petiole × 38. D, *Myoporum laetum* Forst. Young stem × 12. E, *Martynia fragrans* Lindl. Stem × 5. F, *Globularia cordifolia* Linn. Flower peduncle × 20. G, *Selago galpinii* Schlecht. Stem × 23. H, *Hebenstretia* sp. Young stem × 22. I, *Myoporum serratum* R. Br. Stem × 12.

e. Endodermis. *h.p.* Hollow pith. *l.p.* Lignified pith, with some of the central cells breaking down. *s.c.* Secretory cavity. *u.f.* Unlignified fibres. (In Fig. I numerous bundles of yellow acicular crystals occur in the xylem, phloem, and cortex.)

simple pits in the radial walls; Record and Hess (1886) describe the pits in *Bontia* as indistinctly bordered; walls rather thick to very thick. With chambered crystals in *Eremophila bignoniflora.* Length 0·6–1·3 mm.

TAXONOMIC NOTES

Oftia differs from the rest of the family in having intraxylary phloem in the axis when sufficiently mature, and in the absence of secretory cavities.

ECONOMIC USES

Budda or Bastard Australian Sandalwood, *Eremophila mitchelli* Benth., is the source of a so-called Sandalwood in Queensland, and Naio, *Myoporum sandwicensis* (DC.) A. Gray, is reported (1886) to have formerly supplied a low-grade Sandalwood in Hawaii.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Bontia, Eremophila, Myoporum,* Oftia, Pholidia.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

(Bontia), Eremophila, Myoporum.

LITERATURE

(i) *On General Anatomy*

Wood **2457**.

(ii) *On Wood Structure*

Brown, F. B. H. **282**, Howard **1088**, Metcalfe **1497**, Record **1843**, **1851**, Record and Hess **1886**.

207. SELAGINACEAE AND GLOBULARIACEAE

(FIG. 244 on p. 1026; FIG. 245 on p. 1028)

SUMMARY

Small ericoid herbs and undershrubs which occur in South and East Africa and the Mascarene Islands. One of the few anatomical features which appears to be characteristic of these families is the small **glandular hairs** (Fig. 245 A–C) each having a short stalk cell and a head of 2, or, more rarely, 4 convexly arched cells separated from one another by vertical walls. These hairs occur in all investigated genera and species, and sometimes secrete calcareous material in the form of scales, which fill the pits at the bases of which the hairs are situated.

LEAF

Structure variable, ranging from dorsiventral to centric even within the single genus *Globularia*; the lamina in some species with centric structure consists of palisade cells, but in others of isodiametric cells. Besides the **glandular hairs** (Fig. 245 A–C) described in the summary, short uniseriate trichomes also occur. **Stomata** present on both surfaces in all investigated

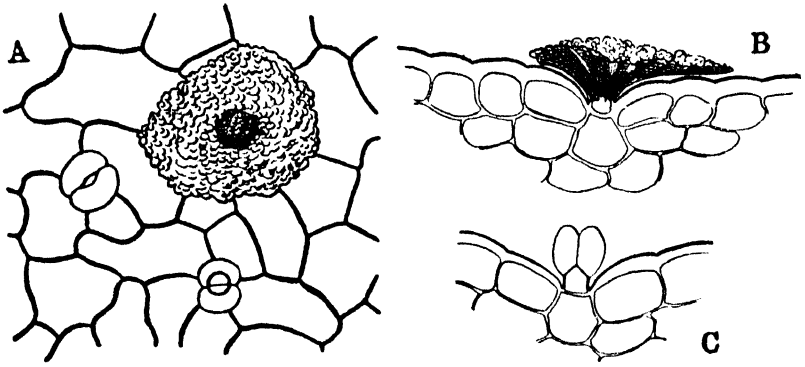


FIG. 245. *SELAGINACEAE*

Chalk glands of *Selago spuria* L.: A, Superficial section of the leaf with one external gland, covered by a scale of lime, and another decalcified; B, Gland with calcareous scale in section; C, Gland in section after the solution of the scale.—Solereder.

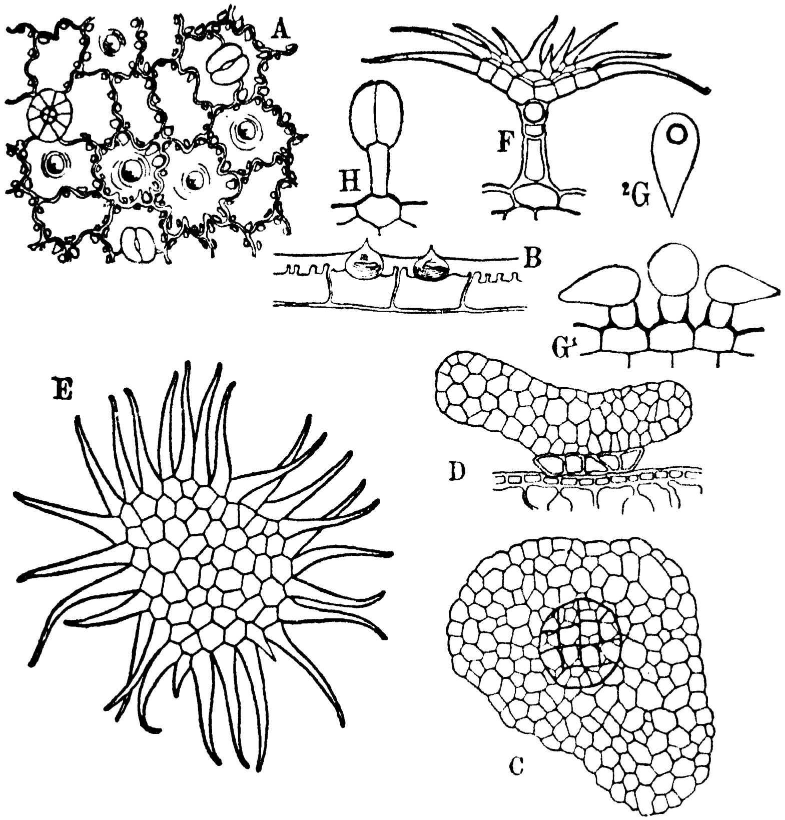


FIG. 246. *VERBENACEAE*

A–B, *Petrea volubilis* L.: A, Epidermis of the leaf in surface-view, B, in transverse section. C–D, Peltate hair of *Clerodendron squamatum* Vahl. E–F, Peltate hair of *Pityrodia salvifolia* R. Br. G, Trichomes on the surface of the leaf in *Avicennia nitida* Jacq. H, Glandular hair of *Pityrodia salvifolia*.—C–D after O. Bachmann, the remainder by Solereder.

species; usually ranunculaceous but sometimes intermixed with caryophyllaceous or rubiaceous types. **Epidermis** frequently containing chlorophyll in *Globularia*; 2-layered in *G. salicina* Lam. **Mesophyll** of *G. orientalis* Linn. containing branched sclerenchymatous idioblasts. Structure of the **veins** in *Globularia* said by Solereder to be of taxonomic value; consisting of a firmly constructed fibro-vascular system embedded in sclerenchyma in some species, or, in others, of a lax fibro-vascular system vertically transcurrent by collenchyma on one or both sides. One large median and several smaller lateral vascular bundles occur deeply embedded in the mesophyll of '*Hebenstretia tenuifolia*', each strand being surrounded by a sheath of large, parenchymatous cells and the median one vertically transcurrent by collenchyma on the adaxial side. **Petiole** (Fig. 244 C) of *Globularia cordifolia* Linn. examined at Kew found to exhibit, in transverse sections, 3 vascular bundles, the median one being larger than the 2 others. **Crystals** of calcium oxalate rare; where present occurring in the form of small rods or prisms; frequently confined to the epidermis, particularly in the floral organs.

AXIS

YOUNG STEM (Fig. 244 F–H)

An incomplete layer of very large hypodermal cells noted in *Selago galpinii* Schlecht. **Cork** not very fully investigated; arising in the sub-epidermis in species of *Hebenstretia* or, according to Solereder, internally to the pericycle in *Selago*. Primary **cortex** narrow in '*Hebenstretia tenuifolia*' and *Selago galpinii*; outer part frequently collenchymatous; consisting of assimilatory tissue, e.g. in *Hebenstretia* (Fig. 244 H). **Pericycle** said by Solereder to contain isolated groups of sclerosed parenchyma or fibrous cells in species of *Dischisma*, *Globularia*, *Hebenstretia*, *Selago*, but no pericyclic sclerenchyma observed in species of *Hebenstretia* and *Selago* examined at Kew. **Xylem** generally in the form of a continuous cylinder traversed by rays 1–2 cells wide, the component ray cells described by Solereder as appearing somewhat prosenchymatous in tangential sections. Xylem of *Globularia cordifolia* Linn. apparently devoid of medullary rays, the minute crowded vessels being arranged in radial multiples. Vessels in '*Hebenstretia tenuifolia*' and *Selago galpinii* mostly solitary, but a few in short, radial multiples, the individual members being somewhat angular and up to about 40 μ radial diameter in '*H. tenuifolia*' and 30 μ in *S. galpinii*; perforations in both species simple; lateral pits horizontally elongated to circular. Wood fibres consisting of elements with fairly wide lumina and thin walls. Wood parenchyma scanty. **Pith** in '*H. tenuifolia*' broad, consisting of thin-walled parenchyma; becoming hollow; rather narrower in *S. galpinii*. Central part of the pith of *Globularia cordifolia* consisting of loose spongy tissue, composed of axially elongated cells which appear circular in transverse sections; perimedullary tissue in the same species composed of similar but more compact cells with thicker walls. **Peduncle** of *G. cordifolia* Linn. as in Fig. 244 F.

TAXONOMIC NOTES

Globularia and certain other genera are, by some authorities, treated as belonging to a distinct family, the Globulariaceae. The structure of the genera concerned is not sufficiently well known for an anatomist to decide whether there are good grounds for recognizing this decision. It is significant, however, that the same type of calcareous gland occurs in *Globularia*, *Hebenstretia*, and *Selago*, i.e. in representatives of both groups.

GENERA DESCRIBED

Dischisma, Globularia,* Hebenstretia,* Selago.*

* Represented in the Kew slide collection.

208. VERBENACEAE

(FIG. 246 on p. 1028; FIG. 247 on p. 1034; FIG. 248 on p. 1036)

SUMMARY

(i) GENERAL

A widely distributed family of very diverse habit, ranging from large forest trees such as Teak (*Tectona grandis* Linn.) to herbs like the Common Vervain (*Verbena officinalis* Linn.). Other members of the family are lianes, and some of these exhibit **anomalous structure** in the wood, e.g. the forked xylem of *Lantana*. Another type of anomalous structure is the succession of xylem rings that is common in *Avicennia*. Species of this genus which grow in mangrove swamps are also remarkable for the possession of **pneumatophores,** in the form of upwardly directed branches of the root system, which extend above the surface of the mud in which the plants grow. A summary of Chapman's (367) work on the morphology and anatomy of *Avicennia nitida* Jacq. is included below (p. 1038). Xerophytes with assimilatory stems and reduced leaves also occur for instance in *Baillonia* and *Verbena*. The young stems are frequently quadrangular or polygonal in transverse section, and in some species definite wings are developed. The leaf is dorsiventral or isobilateral. Many kinds of glandular and non-glandular **hairs** are known to occur, whilst **cystoliths** are fairly frequent in the cells around the bases of the hairs, or the tips of the hairs may themselves be calcified. **Extra-floral nectaries** on the lower surface of the leaf and on the petiole are common in *Clerodendron*. **Stomata** are rather variable in type and occur on one or both surfaces of the leaf. **Crystals** of various kinds widely distributed.

(ii) WOOD

Vessels mostly medium-sized, occasionally with a slight radial, oblique, or tangential pattern, commonly ring-porous, perforations typically simple but with a few scalariform or reticulate plates in some genera, intervascular pitting minute to moderately large and pits to parenchyma usually similar, members of medium length to very short. **Parenchyma** typically paratracheal only, usually narrowly vasicentric, but sometimes more abundant and confluent. **Rays** mostly 3–4 cells wide, but sometimes much wider, heterogeneous to homogeneous. **Fibres** septate in most genera, with simple pits, of medium length to moderately short. **Included phloem** of the 'concentric' type present in *Avicennia*.

LEAF

Dorsiventral or isobilateral. Surface waxy in halophytic species. **Hairs** (Fig. 246) of many diverse kinds, both glandular and non-glandular. For details concerning the occurrence of the different kinds in numerous members of the Verbenoideae see the article by Kunz (1305).

A. Non-glandular hairs. (i) Unicellular trichomes. These include (*a*) short, conical hairs situated on the vertical division walls between adjoining epidermal cells, e.g. in *Vitex agnus-castus* Linn.; (*b*) short, conical, silicified trichomes partly embedded in the thickened outer walls of the epidermal cells in *Petrea volubilis* Linn. (Fig. 246 A–B) and probably in *Teijsmanniodendron*; (*c*) unicellular, 2-armed trichomes in *Lippia nodiflora* Michx.; (*d*) hairs with cystoliths in the cells surrounding their bases in species of *Lantana*, *Lippia* (tips also calcified), *Tectona*, *Verbena*. (ii) Uniseriate hairs of various kinds, widely distributed. These include: (*a*) simple types in *Callicarpa*, *Clerodendron*, *Congea*, *Vitex*; (*b*) with short stalks and long terminal cells in the Stilbeae and in *Pityrodia*; (*c*) bracket-shaped in *Priva*; (*d*) with short stalks and pear-shaped terminal cells attached horizontally and excentrically to the stalks (Fig. 246 G) in *Avicennia*, giving a dull or white appearance to the lower surface of the leaf. (iii) Multicellular peltate hairs recorded in the *Squamata* section of *Clerodendron* (Fig. 246 C–D) and somewhat similar but more branched structures in *Chloanthes* and *Pityrodia* (Fig. 246 E–F). Transitional forms between these and stellate hairs also occur in *Pityrodia*. (iv) Branched, thin-walled trichomes, sometimes appearing to be stellate, have been recorded in species of *Callicarpa*, *Chloanthes*, *Lachnostachys*, *Tectona*, *Verbascum* (candelabra hairs). (v) Hooked trichomes in *Priva* and *Stachytarpheta sanguinea* Mart.

B. Glandular hairs. (i) With very small heads consisting of 1 or only a few cells borne on stalks of variable length (Fig. 246 H) in the Stilbeae as well as in species of *Lantana*, *Lippia*, *Phryma*, *Pityrodia*, *Verbena*. (ii) Short-stalked, disk-shaped or peltate, multicellular glands, e.g. in *Avicennia*, *Citharexylum*, *Holmskioldia*, *Petrea*, *Tectona*; sometimes deeply sunk in the tissue of the leaf and giving rise to transparent dots, e.g. in species of *Callicarpa* and *Clerodendron*.

Extra-floral nectaries occur on the lower surface of the leaf in various species of *Clerodendron*; each gland exhibiting, in transverse section, a palisade-like epidermis, subtended on the inside by a layer of polygonal tabular cells with the perpendicular walls suberized. Nectaries also recorded on the leaf surface or petiole in species of *Amasonia*, *Baillonia*, *Callicarpa*, *Casselia*, *Citharexylum*, *Dipyrena*, *Duranta*, *Lampaya*, *Monochilus*, *Rhaphithamnus*, *Stachytarpheta*.

Epidermis of members of the Stilbeae and of certain species of *Chloanthes*, *Lachnostachys*, *Pityrodia* with rolled leaves, generally composed of cells with very large lumina. A **hypoderm** of several layers of cells present on the upper side of the leaf of *Avicennia*, occupying half the thickness of the lamina in *A. officinalis* Linn., but not so wide in some of the other species. Hypoderm also recorded by Kienholz (1236) in *Vitex*.

Stomata (Bider 196, Holm 1002, Kunz 1305, Mullan 1569, Sabnis 1977) present on both surfaces or confined to the lower side; recorded on both surfaces in species of *Amasonia* (pro parte), *Baillonia*, *Bouchea* (most species), *Casselia* (a few species), *Citharexylum* (pro parte), *Dipyrena*, *Hierobotana*, *Lampaya*, *Lantana*, *Priva*, *Stachytarpheta* (most species), *Tamonea*, *Urbania*, *Verbena*; confined to the lower surface in *Amasonia* (pro parte), *Bouchea* *incisa* Rusby, *Casselia* (most species), *Citharexylum* (pro parte), *Coelocarpum*, *Duranta*, *Lippia*, *Monochilus*, *Petrea*, *Phryma*, *Rhaphithamnus*, *Stachytarpheta* (a few species), *Tatea*, *Vitex*. Stomata mostly caryophyllaceous in *Amasonia*, *Avicennia*, *Bouchea* (pro parte), *Casselia*, *Monochilus*, *Petrea*, *Stachytarpheta* (most species), *Tamonea*, *Tatea*, and less frequently in *Bouchea* (pro parte) and *Stachytarpheta* (pro parte). Rubiaceous stomata, occurring sporadically amongst other kinds, recorded in *Bouchea* (pro parte), *Casselia*, *Petrea* (pro parte), *Stachytarpheta* (pro parte), *Teijsmanniodendron*, and stomata not accompanied by definite subsidiary cells (ranunculaceous types) in *Baillonia*, *Citharexylum*, *Clerodendron*, *Coelocarpum*, *Dipyrena*, *Duranta*, *Hierobotana*, *Lampaya*, *Neosparton*, *Phryma*, *Priva*, *Rhaphithamnus*, *Stachytarpheta* (a few species), *Urbania*. Guard cells of stomata, according to Kunz (1305), small in *Casselia* (pro parte), *Coelocarpum*, *Neosparton*, *Tatea*, *Urbania*, and of variable size in *Amasonia*, *Casselia* (pro parte), *Petrea* (pro parte). Stomata on the upper surface of a few species of *Stachytarpheta* said to be arranged in groups.

Mesophyll (Solereder 2158, Bider 196, Kunz 1305). Homogeneous in *Urbania*; consisting wholly of compact palisade tissue in *Vitex* sp. (1236); isobilateral in *Lampaya*. One layer of palisade tissue, with only occasional transverse septa in the palisade cells, in *Baillonia* (pro parte), *Bouchea* (pro parte), *Citharexylum* (pro parte), *Dipyrena*, *Priva* (pro parte), *Stachytarpheta* (pro parte). Palisade 1-layered, but with irregularly distributed transverse walls, in *Casselia*, *Tamonea* (pro parte), *Tatea*. Palisade consisting of several layers of cells in *Amasonia*, *Baillonia* (pro parte), *Bouchea* (pro parte), *Citharexylum*, *Coelocarpum*, *Duranta*, *Hierobotana*, *Lantana*, *Lippia*, *Monochilus*, *Petrea*, *Priva*, *Rhaphithamnus*, *Stachytarpheta* (pro parte), *Tamonea* (pro parte), *Verbena*. Vascular bundles of the larger **veins** accompanied by sclerenchyma in species of *Baillonia*, *Casselia*, *Citharexylum* (most species), *Coelocarpum*, *Duranta*, *Lampaya*, *Lippia*, *Petrea*, *Rhaphithamnus*, *Stachytarpheta*, *Verbena*; sclerenchyma also present around the smaller vascular bundles in *Avicennia* (Mullan 1571), *Baillonia amabilis* Bocq., *Casselia* (pro parte), *Citharexylum* (pro parte), *Petrea*, *Rhaphithamnus*, *Stachytarpheta* (pro parte). Individual sclerenchymatous fibres extend into the mesophyll in *Citharexylum* (pro parte) and *Petrea* (pro parte). Storage-tracheids with pitted walls recorded in the mesophyll of *Avicennia officinalis* by Mullan (1571). Vascular bundles not accompanied by sclerenchyma in *Amasonia*, *Baillonia juncea* Benth. et Hook., *Bouchea*, *Casselia*, *Citharexylum sessaei* Don., *Dipyrena*, *Hierobotana*, *Monochilus*, *Priva*, *Stachytarpheta* (pro parte), *Tamonea*, *Urbania*. Vascular bundles described by Mullan (1569) as vertically transcurrent by water-storage tissue in *Vitex* sp.

Petiole (Fig. 247 A–F and K), when examined at Kew, exhibiting, in transverse sections through the distal end, a shallow, crescentic, median vascular strand in species of *Lantana* (Fig. 247 D), *Lippia*, *Verbena*; a deeper crescentic strand in species of *Calicarpa*, *Citharexylum*, *Lantana*, *Vitex* (Fig. 247 B); a crescentic strand with incurved ends in *Caryopteris* (Fig. 247 E) and *Clerodendron* (Fig. 247 C), the xylem being dissected into separate groups in contact with a continuous arc of phloem in the last genus. Median vascular strand consisting of an almost closed cylinder of xylem, surrounded by completely closed cylinders of phloem and fibres, in *Petrea* (Fig. 247 K), and of an interrupted circle of widely spaced, collateral bundles in *Oxera* (Fig. 247 A). Accessory bundles in the wings observed in species of *Callicarpa*, *Caryopteris*, *Citharexylum*, *Clerodendron*, *Duranta*, *Lantana*, *Lippia*, *Petrea*, *Sphenodesma*, *Verbena*, *Vitex* and enclosed within the median strand in an approximately medullary position in *Lantana*, *Lippia*, and *Vitex*. For further details concerning medullary bundles in the petiole of the Verbenaceae see Hubert (1105) and Perrot and Hubert (1696). A circular median strand recorded by Solereder in the petiole of *Avicennia* and an arc-shaped bundle accompanied on the upper side by 1 or 2 additional pairs of bundles in *Congea* and *Symphorema*. Petiolar vascular bundles described by Solereder as exhibiting a scalariform arrangement in *Premna scandens* Roxb.

Crystals (Kunz 1305) in the form of small needles or prisms, widely distributed in the parenchymatous tissues of both leaf and axis. Small needles recorded in *Baillonia*, *Casselia* (pro parte), *Citharexylum* (pro parte), *Dipyrena*, *Duranta*, *Petrea*, *Tatea*. Large needles present in *Citharexylum* (pro parte). Large and small prismatic crystals recorded in *Citharexylum caudatum* Linn., *C. hexangulare* Greenm., and *Stachytarpheta lychnitis* Mart. and large solitary crystals in *Casselia* (pro parte) (in chambered fibres), *Petrea*, *Tectona*. Sphaerocrystalline masses recorded in the epidermis of *Campylostachys* (see also under 'Young Stem', p. 1035).

For detailed structure of the leaf of species of Verbenaceae that have been used in medicine see Hubert (1105).

AXIS

YOUNG STEM (Fig. 247 G–J and L)

Young stem commonly quadrangular or polygonal in transverse section (Fig. 247 J and L); provided with wings in a few Chloantheae and Stilbeae. Especially large wings, containing abundant assimilatory tissue and supplied by a system of vascular bundles, present in species of *Chloanthes*. Wings shaped like a T in transverse sections occurring in *Xeroplana zeyheri* Briq., and similar but less well-developed ones in *Spartothamnella juncea* Briq. A collenchymatous **hypoderm,** including isolated or clustered lignified cells, recorded by Mullan (1571) in *Clerodendron inerme* Gaertn. **Cork** originating superficially in *Aegiphila*, *Avicennia*, *Callicarpa*, *Caryopteris*, *Citharexylum*, *Clerodendron*, *Congea*, *Duranta*, *Oxera*, *Petrea*, *Priva*, *Sphenodesma*, *Stachytarpheta*, *Symphorema*, *Tectona*, *Vitex*; more deeply seated in the Stilbeae, according to Solereder, and in species of *Lantana* and *Lippia* examined at Kew. Cork cells thin-walled in *Citharexylum quadrangulare* Jacq., *Vitex agnus-castus* Linn., and *Tectona grandis* Linn., but some of them said to be strongly thickened on the inner tangential walls in the last species; tabular and thickened on the outer tangential walls in *Petrea arborea* H. B. et K. Cork of *Clerodendron inerme* composed of phelloid cells according to Mullan (1571). Primary **cortex** frequently collenchymatous; sometimes assimilatory (Fig. 247 H); seen to include stone cells in *Tectona grandis* (Fig. 247 J). Secondary cortex in specimens of *Clerondendron inerme* growing just above high-water mark described by Mullan (1571) as very lacunar and as supported by groups of stone cells. Secondary cortex of *Avicennia officinalis* Linn. also very lacunar. **Endodermis** with casparian thickenings noted in *Verbena* sp. and said by Holm (1002) to be present, but difficult to detect, in *Phryma*. Endodermis

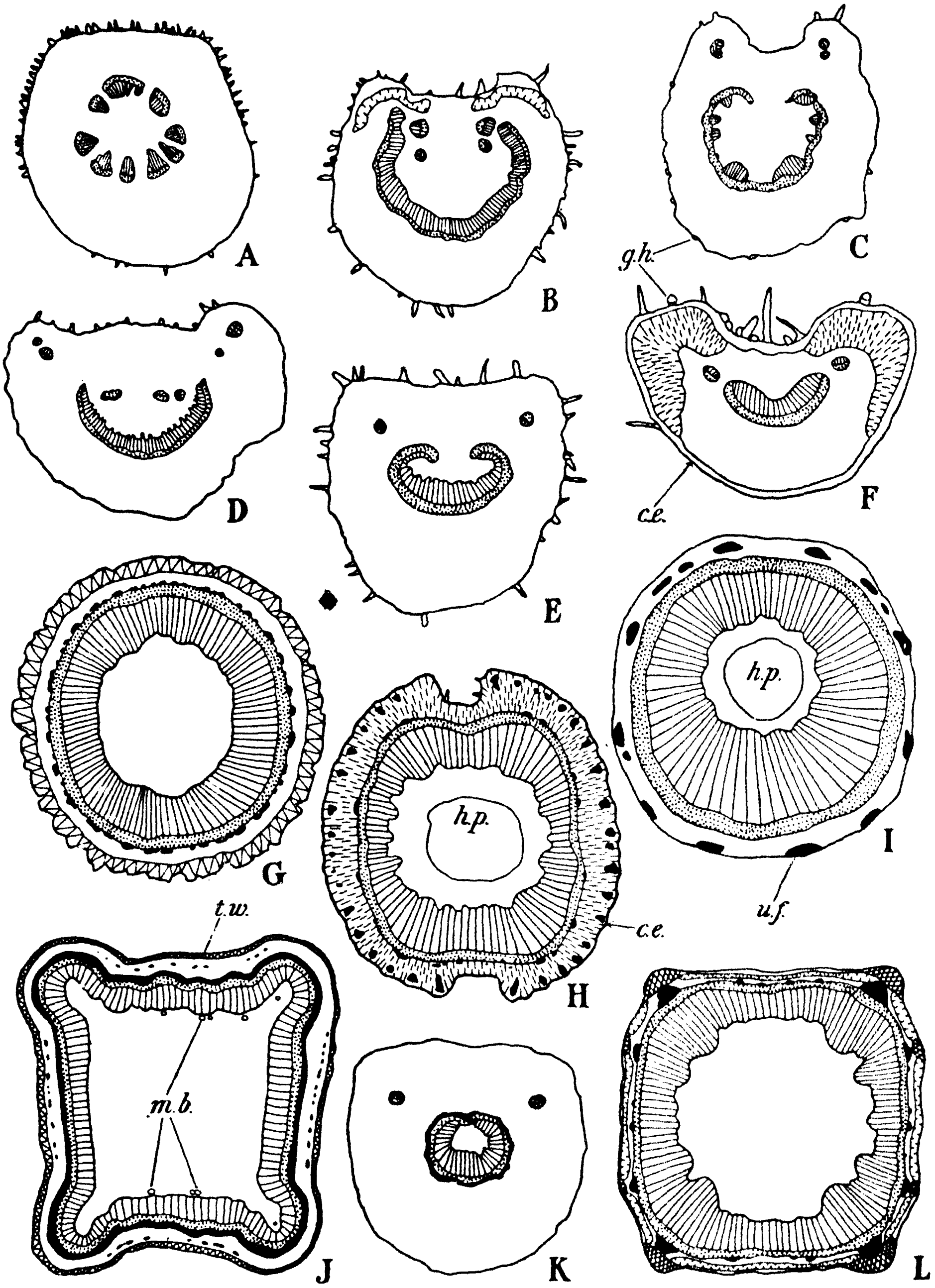


FIG. 247. *VERBENACEAE*

A, *Oxera pulchella* Labill. Petiole ×24. B, *Vitex negundo* Linn. Petiole ×20. C, *Clerodendron fargesii* Dode. Petiole ×22. D, *Lantana camara* Linn. Petiole ×21. E, *Caryopteris tangutica* Maxim. Petiole ×34. F, *Baillonia juncea* Briq. Petiole ×44. G, *Callicarpa japonica* Thunb. Stem ×17. H, *Baillonia juncea* Briq. Stem ×13. I, *Lippia citriodora* H. B. et K. Stem ×13. J, *Tectona grandis* Linn. Stem ×6. K, *Petrea volubilis* Linn. Petiole ×15. L, *Verbena officinalis* Linn. Stem ×13.

c.e. Cutinized epidermis. *g.h.* Glandular hairs. *h.p.* Hollow pith. *m.b.* Medullary bundles with central phloem. *t.w.* Thin-walled cork. *u.f.* Unlignified fibres. In Fig. A a few conspicuous solitary crystals occur in the 'cortex'. In Fig. J xylem vessels up to 124 μ in diameter.

observed by Sayeedud-Din and Moinuddin (2016) in *Holmskioldia*. **Pericycle** most frequently containing isolated bundles of sclerenchymatous elements; a composite and continuous ring recorded or observed only in species of *Avicennia*, *Clerodendron*, *Petrea*, *Sphenodesma*, *Tectona* (Fig. 247 J). No pericyclic sclerenchyma noted at Kew in species of *Priva*. Pericyclic sclerenchyma seen to include stone cells as well as fibres in species of *Clerodendron*, *Duranta*, *Oxera*, *Petrea*, and *Sphenodesma*. Secondary **phloem** including fibres, sometimes accompanied by stone cells, in species of *Callicarpa*, *Chloanthes*, *Cyanostegia*, *Eurylobium*, *Lippia* (stone cells), *Pityrodia*, *Premna* (Dop 598), *Sphenodesma* (bands of sclerosed cells); *Symphorema*, *Tectona*, *Vitex*; phloem sometimes completely sclerosed, apart from the sieve tissue, in *Chloanthes* and *Pityrodia*. **Xylem** in the form of a continuous cylinder, usually traversed by narrow rays, in all of the species examined at Kew, but a few relatively broad, lignified rays noted in the more woody genera, e.g. *Tectona* and *Vitex*. The rays become much broader in the mature wood. (See 'Wood'.) Herbaceous stems of *Phryma* described by Holm (1002) as having a separate collateral bundle in each angle of the quadrangular stele. Vessels usually with simple perforations. See also under 'Wood'. **Intraxylary phloem** said by Mullan (1571) to be present in stems of *Avicennia officinalis* Linn. when 3 mm. thick but to disappear from older material.

Numerous **medullary bundles** recorded by Solereder in *Teijsmanniodendron*, and a few observed at Kew in the outer part of the pith of *Tectona grandis* (Fig. 247 J). **Pith** homogeneous in the Stilbeae; sometimes heterogeneous in *Lantana*; becoming fistular at an early stage in *Phryma*. Pith of *Avicennia officinalis* including elongated sclerenchymatous elements, but becoming completely lignified when more mature according to Mullan (1571), usually composed of thick-walled cells in the Chloantheae. Large **secretory cells** recorded in the primary cortex and phloem of *Congea* and *Symphorema*. Abundant solitary **crystals** in the pericycle, closely associated with the sclerenchyma and sometimes enclosed within the stone cells, observed at Kew in species of *Clerodendron*, *Duranta*, *Oxera*, *Petrea*, *Sphenodesma*, and *Tectona*. A golden-brown crystalline deposit noted in the epidermis and outer part of the cortex of *Priva laevis* Juss.

WOOD (Fig. 248)

Vessels mostly medium-sized (100–200 μ mean tangential diameter), but very small (25–50 μ) in some of the shrubby species, e.g. of *Duranta*, *Lantana*, and *Rhaphithamnus*; sometimes of 2 distinct sizes in the climbers; mostly solitary in *Citharexylum* and, according to Williams (2430) in *Aegiphila*, often with numerous radial multiples of 4 or more cells in *Avicennia*, with a radial or oblique pattern in *Lippia* p.p. and *Vitex* p.p. (1836), and with a tendency to a tangential pattern in some species of *Callicarpa* (Fig. 248 D), *Clerodendron* (1206), *Peronema*, and *Vitex*; very variable in number, ranging from fewer than 5 per sq. mm. in some species of *Avicennia*, *Geunsia*, *Premna*, and *Teijsmanniodendron*, to 20–40 per sq. mm. in some species of *Avicennia*, *Petitia*, *Pseudocarpidium*, *Rhaphithamnus*, and *Tectona*, and more than 40 in some of the shrubby species; ring-porous or semi-ring-porous in some species of *Aegiphila*, *Callicarpa*, *Citharexylum*, *Clerodendron*, *Congea*, *Cornutia*, *Gmelina* (423), *Lippia*, *Peronema*, *Tectona*, and *Vitex*; fine spiral thickening observed in *Lippia* p.p. and reported (1851) in *Caryopteris* and *Geunsia*. Perforations exclusively simple, except for rare reticulate plates in *Vitex alata* Roxb. (2254) and a few scalariform plates in some species of *Vitex* (1154, 1890). Intervascular pitting very small to minute in *Avicennia*, *Callicarpa*, *Citharexylum*, *Clerodendron*, *Duranta*, *Lantana*, *Peronema*, and *Rhaphithamnus*,

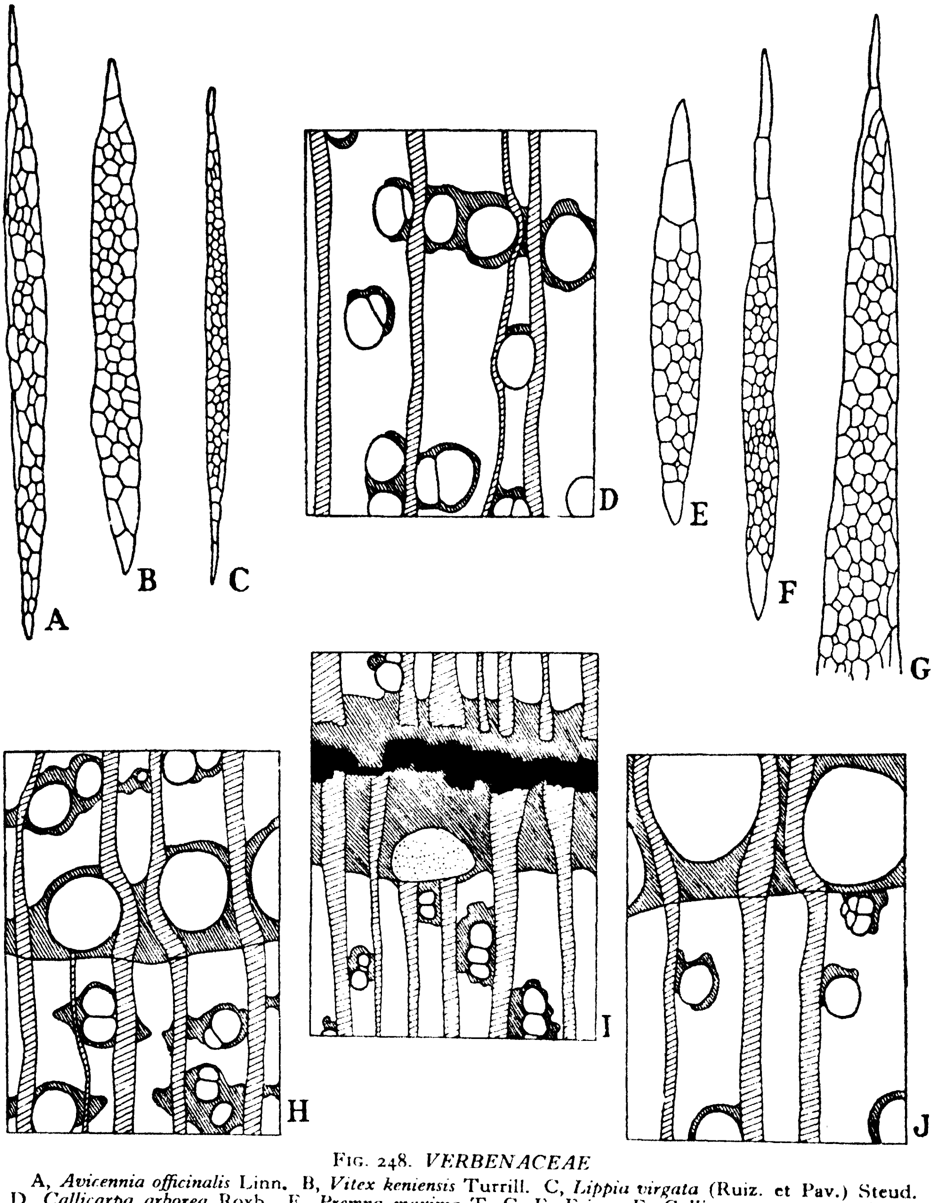


FIG. 248. *VERBENACEAE*

A, *Avicennia officinalis* Linn. B, *Vitex keniensis* Turrill. C, *Lippia virgata* (Ruiz. et Pav.) Steud. D, *Callicarpa arborea* Roxb. E, *Premna maxima* T. C. E. Fries. F, *Callicarpa tomentosa* Willd. G, *Cornutia grandifolia* (S. et C.) Schauer. H, *Vitex fosteri* C. H. Wright. I, *Avicennia officinalis* Linn. J, *Tectona grandis* Linn.

moderately large in the other genera; pits to ray and wood parenchyma usually similar, but occasionally simple, and with some elongated pits in species of *Clerodendron*, *Cornutia*, *Petitia*, *Teijsmanniodendron*, and *Vitex*, and, less commonly, in *Gmelina* and *Premna*. Solid deposits of various types sometimes present, e.g. white deposits in *Tectona* and *Vitex*, the former of calcium phosphate (1154), and yellow deposits of lapachol in *Avicennia*; calcium carbonate occurs in *Citharexylum* and *Lippia* (1890) and silica in *Peronema* (1154), *Tectona* (2158), and *Teijsmanniodendron* (1154); Solereder refers to silica as present in all the elements in *Petrea*. Tyloses, which often have large simple pits, are present and often abundant in some species of *Callicarpa*, *Gmelina*, *Petitia*, *Premna*, *Pseudocarpidium* (1890), *Tectona*, and *Vitex*, and are sclerotic in *Pseudocarpidium* (1890). Mean member length 0·2–0·5 mm. **Parenchyma** typically exclusively paratracheal, though there may occasionally be a few cells scattered among the fibres, e.g. in *Vitex*; usually as a few cells or narrow sheaths round the vessels, rather more abundant and aliform or confluent in some species of *Aegiphila*, *Avicennia*, *Callicarpa*, *Citharexylum* (2158), *Gmelina*, and *Peronema*; Dadswell and Eckersley (525) refer to fine metatracheal bands in *Vitex lignum-vitae* A. Cunn.; occasionally in narrow terminal bands, e.g. in *Gmelina*[1] and *Vitex*, and sometimes in broad bands associated with the pore-zone, e.g. in *Tectona*; very rare or absent from *Duranta* and *Lantana*. Crystals rare, but Janssonius (1154) refers to needle-shaped crystals in some species of *Premna* and *Gmelina* and to chambered crystals in *Vitex bantamensis* Koord. et Valet. The chemical composition of the crystals in *Gmelina leichardtii* F. v. M. has been described by Smith (2151). Strands of 2–8, usually 4, cells. Tending to be storied in *Congea tomentosa* Roxb. **Rays** 1–12 cells wide, mostly up to 3–4 cells; exclusively uniseriate in *Pseudocarpidium*, 5 or more cells wide in some species of *Avicennia*, *Callicarpa*, *Clerodendron*, *Congea*, *Cornutia*, *Gmelina*, *Premna*, *Tectona*, and *Vitex*, and reported (1890) to be up to 12 cells wide in *Petrea*; usually less than 1 mm. high and sometimes very short, but often more than 1 mm. high in some species of *Aegiphila*, *Avicennia*, *Clerodendron*, *Congea*, *Duranta*, *Lantana*, and *Vitex*; uniseriate rays often few, e.g. in *Congea*, *Gmelina*, *Premna*, and *Vitex*, usually composed of upright cells only, but sometimes of mixed upright and procumbent cells; 3–13 rays per mm.; heterogeneous (Kribs's Type II A and B) to homogeneous (Kribs's Type II); with 4 or more marginal rows of square or upright cells in some species of *Aegiphila*, *Avicennia*, *Callicarpa*, *Duranta*, *Geunsia*, *Lantana*, and *Rhaphithamnus*; homogeneous in some species of *Tectona* and *Vitex*; with sheath cells and patches of tissue filled with crystals in the only available specimen of *Cornutia grandifolia* (S. et C.) Schaur.; composed entirely of upright and square cells in *Clerodendron buchholzii* Gürke and some species of *Avicennia*. Crystals rather rare, but observed in some species of *Avicennia* and *Vitex*; Janssonius (1154) refers to needle-shaped crystals in some species of *Geunsia*, *Gmelina*, and *Premna* and Gonggrijp (794) to silica in *Avicennia* and *Vitex*. With a tendency to storied arrangement in some of the woods with low rays, e.g. *Citharexylum* spp. and *Gmelina leichhardtii* F. v. Müll. **Fibres** typically septate, but non-septate in *Avicennia* and *Peronema* and in some specimens of species of *Petrea* (1890) and *Vitex*, e.g. *V.*

---

[1] Chowdhury (423) states that these cells are found at the beginning of the season's growth and should therefore be called 'initial' rather than 'terminal'.

longeracemosa Pittier (1894), and with relatively few septate fibres in *Clerodendron* and *Lantana* (1890); Solereder notes septate fibres in the following genera not examined by the author: *Campylostachys*, *Chloanthes*, *Euthystachys*, *Petrea*, *Stilbe*, and *Symphorema*. Pits simple and mostly on the radial walls, but small borders recorded (1890) in *Petrea arborea* H. B. et K. Walls typically of medium thickness to thin, thick only in *Avicennia* and some species of *Lippia* and *Vitex*. Silica reported (794) in *Peronema* and *Teijsmanniodendron*, and deposits rich in flavone derivatives common in *Premna* and *Vitex* (1206, 1679). Mean length 0·8–1·4 mm. **Included (interxylary) phloem** of the 'concentric' type (*c.l. circumvallatum*) present in *Avicennia*, with layers of xylem separated by layers of phloem and conjunctive tissue; each layer of conjunctive parenchyma contains a row of stone cells 2–6 cells wide and isolated strands of phloem, which are circular to oval in cross-section. The xylem layers are occasionally interrupted by interfascicular rays. See also 'Anomalous Structure' below.

ROOT

Phryma leptostachya Linn., described by Holm (1002) as having primary nutritive roots and secondary storage roots, the latter provided with a contractile exodermis and deposits of starch in the cortex and pith. Endodermis in the same species thin-walled. Species of *Avicennia* growing in mangrove swamps are provided with negatively geotropic root-branches. See 'Physiological Anatomy', below.

ANOMALOUS STRUCTURE

Forked xylem recorded in *Lantana*. Successive rings of bundles occur in shrubby or arboreal species of *Avicennia*. In this genus the original ring of vascular bundles is bounded externally by a composite and continuous ring of sclerenchyma. The phloem is in the form of isolated strands separated by lignified medullary rays, which constitute bridge-like connexions between the xylem and the sclerenchymatous ring. The first ring of bundles is scarcely less than 1 mm. thick. It is followed by parenchymatous tissue and then by the second ring of vascular bundles, which arises in an extra-fascicular position and is adjoined externally by a sclerenchymatous ring, composed of 1 or 2 layers of short cells. The first ring of growth is no broader than the original ring of vascular bundles, and its phloem is again differentiated in the form of groups of cells, separated by strips of woody tissue; the latter, which consists of medullary rays, wood fibres, and vessels, serves to connect the ring of xylem with that of sclerenchyma. This is followed by a second and third extra-fascicular vascular ring. See also Mullan (1571) and under 'Wood'.

PHYSIOLOGICAL ANATOMY

The physiological anatomy of halophytes and species from mangrove swamps belonging to this family has been the object of a number of investigations. Recent work by Chapman[1] (367) on the morphology of *Avicennia nitida* Jacq. has shown that, about 30 days after emergence from the testa, 2 types of seedling can be distinguished; in the one there is a poorly developed fibrous root system, the cotyledons soon disappear, and the stem becomes woody; in the other, root development is good, the cotyledons persist for a longer period, and the stem does not become woody so rapidly. During the first 6 days after emergence from the testa (the plant is viviparous) the root system is so poorly developed that establishment may be precarious. In the adult plant 5 types of root can ultimately be distinguished: (i) primary adventitious roots, (ii) pneumatophores, (iii) horizontal roots, (iv) anchoring roots, (v) absorbing roots.

---

[1] The following summary of his own work was kindly contributed by Professor V. J. Chapman.

The cotyledons possess numerous small air spaces whilst the cells are packed with starch, fat, and protein. At the base of the cotyledons and leaves there is a dense conglomeration of glands and hairs, whilst 3 bundles form the vascular supply. The mature leaf bears glands on the upper surface and there is a sub-epidermal water-storage tissue. Patches of tracheids are distributed between the palisade and spongy mesophylls, whilst on the under surface there are peculiar trichomes with 'anvil-like' heads. Another interesting feature of the leaves is provided by the lenticel hydathodes which generally occur on the upper surface.

In the pith and cortex of the stem the characteristic air spaces are formed by the rounding off of the cells at their corners. In its early stages the hypocotyl possesses a hairy covering which persists until elongation (primarily due to cell extension) takes place. Secondary thickening in the stem is typical of the genus and is brought about by successive rings of extra-fascicular cambium that arise in the pericycle.

The secondary adventitious roots, which have a tendency to arise in decussate pairs, develop very early. There are 2 zones in the cortex of these roots, the air spaces first arising in the inner cortex. In all the various root types much elongation of the individual cells produces a strain upon the radial cell rows of the cortex so that 'buckling' takes place and large longitudinal air spaces result. The radial plates permit of ready air-flow in a longitudinal but not in a circular direction. In the cortex of the adventitious roots mechanical support cells develop in series, but in the pneumatophores these idioblasts tend to be isolated. Two types of pneumatophore can be recognized: (i) the smooth with a thick cork sheath, and (ii) the rough with a thin cork sheath. Both types possess an apical cork sheath and statolith area. The aerial portions of the pneumatophores are plentifully supplied with lenticels, whilst the distribution of the subsurface absorbing roots borne by the pneumatophores is related to the rate of accretion.

An important anatomical feature is the existence of a 'closing layer' around the origin of every branch-root or rootlet because it must limit the rate of gaseous diffusion. It seems, therefore, that each pneumatophore is only functional for the immediate adjacent region of underground root. Another phenomenon, which may be encountered in any of the root types, is the development of secondary cortex with smaller air spaces from a phellogen which grows across the primary cortex, thus cutting off a considerable portion that subsequently dies. The causal factors responsible for this are still unknown.

Earlier accounts of the anatomy of the roots of *Avicennia* have been published by Emould (627), Liebau (1368), Mullan (1571), and Trochain and

Dulau (2281). It is noteworthy that, according to Liebau, the cork in the roots is lignified and not suberized.

Mullan (1569) has described for *Clerodendron inerme* Gaertn. how the leaves become thick and succulent at the end of the monsoon period and serve for water-storage. In the root of the same species there are radially arranged lacunae in the cortex, whilst the cork, which originates in the pericycle, is composed of more or less lignified phelloid cells.

TAXONOMIC NOTES

It is a matter of opinion whether *Phryma* should be classified in a tribe of the Verbenaceae or should be given the status of a distinct family. For further remarks on this subject see Holm (1002) and the literature which he cites.

The wood structure is fairly uniform throughout the family, with the exception of *Avicennia*, which has anomalous structure and thick-walled, non-septate fibres.

ECONOMIC USES

Tectona grandis Linn. f. is the source of Teak, which is outstanding as a timber on account of its combination of great durability with freedom from warping under the most exacting conditions. It is used all over the world for purposes that demand these qualities and is unrivalled for shipbuilding, particularly for decking. *Gmelina* spp., particularly *G. arborea* Roxb., and *Vitex* spp. also produce good timbers, but, owing to limited supplies or small dimensions, these are not of more than local importance. *Gmelina arborea* has of recent years been widely used in forestry plantations in Tropical Africa. 'Oil of Verbena' is distilled in the south of France from the leaves of *Lippia citriodora* H. B. et K. Medicinal properties have been attributed to various members of the family, but are not of great importance. The anatomical structure of some of the species with reputed medicinal properties has been described by Hubert (1105). The thin bark of *Avicennia* has been used in tanning according to Baker (103) and Wenzel (2412), and a description of its microscopical structure is included in Wenzel's account. The bark is characterized by a broad layer of cork composed of thick-walled cells arranged in radial rows; rosette-shaped groups of cells, visible in transverse sections, on the inside of the cork and subjacent parenchyma; stone cells and parenchymatous cells filled with acicular crystals, both situated internally to the rosette-like groups; a ring of about 2 layers of stone cells constituting the inner surface of the bark; and the absence of medullary rays. The leaves of *Priva echinata* Juss. and *Stachytarpheta dichotoma* Vahl. have been used as tea. *Priva laevis* Juss. has edible tubers.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Aegiphila, Amasonia, Avicennia, Baillonia, Bouchea, Callicarpa,* Campylostachys, Caryopteris,* Casselia, Chloanthes, Citharexylum,* Clerodendron,* Coelocarpum, Congea, Cyanostegia, Dipyrena, Duranta,* Eurylobium, Hierobotana, Holmskioldia, Lachnostachys, Lampaya, Lantana,* Lippia,* Monochilus, Neosparton, Oxera,* Petrea, Phryma, Pityrodia, Premna, Priva,* Rhaphithamnus, Spartothamnella, Sphenodesma,* Stachytarpheta, Symphorema, Tamonea, Tatea, Tectona,* Teijsmanniodendron, Urbania, Verbascum, Verbena,* Vitex,* Xeroplana.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Aegiphila, Avicennia, Callicarpa, (Campylostachys), (Caryopteris), (Chloanthes), Citharexylum, Clerodendron, Congea, Cornutia, Duranta, Espadaea, Geunsia, Gmelina, Lantana, Lippia, Peronema, Petitia, (Petrea), Premna, Pseudocarpidium, Rhaphithamnus, (Stilbe), (Symphorema), Tectona, (Teijsmanniodendron), Vitex.

LITERATURE

(i) *On General Anatomy*

Baker **103**, Bider **196**, Chapman **367**, Coster **479**, Dop **598**, Emould **627**, Holm **1002**, Hubert **1105**, Kienholz **1236**, Kunz **1305**, Liebau **1368**, Mullan **1569**, **1571**, Perrot and Hubert **1696**, Sabnis **1977**, Sayeedud-Din and Moinuddin **2016**, Trochain and Dulau **2281**, Wenzel **2412**.

(ii) *On Wood Structure*

Baker **103**, Becking *et al.* **164**, Beekman **167**, den Berger **179**, **182**, Besson **186**, Bianchi **194**, Bournot **246**, Brit. Hond. For. Dept. **274**, Burgerstein **310**, Chalk and Chattaway **362**, Chowdhury **411**, **423**, Cooper and Record **461**, Cormio **474**, Coster **478**, **480**, **481**, Cozzo **494**, Dadswell and Eckersley **525**, Foxworthy **705**, Garratt **744**, Geiger **754**, Gonggrijp **794**, Greguss **2522**, Howard **1088**, Janssonius **1154**, Jolly **1188**, Jones **1191**, Kanehira **1206**, **1209**, Lecomte **1334**, Méniaud **1492**, Normand **1606**, Panshin **1649**, Pearson and Brown **1679**, Pereira **1687**, Pfeiffer, H. **1712**, Record **1783**, **1836**, **1843**, **1851**, Record and Hess **1886**, **1890**, Record and Mell **1894**, Smith, H. G. **2151**, Stone **2203**, Tang **2231**, Thompson **2254**, Tupper **2295**, Williams **2430**, Yamabayashi **2478**.

209. LABIATAE

(FIG. 249 on p. 1042; FIG. 250 on p. 1044; FIG. 251 on p. 1046; FIG. 254 on p. 1058)

SUMMARY

(i) GENERAL

This widely distributed family includes plants with a considerable variety of habit forms. Most of the familiar species are herbs, often with wiry stems, but some genera tend to be shrubby, e.g. *Lavandula*, *Rosmarinus*. Many species occur in arid habitats and show marked xerophytic characters, but a few which occur in marshy places (*Dysophylla*, *Mentha*, *Scutellaria*) have well-developed intercellular spaces in the cortex of the young stem. The branches are very frequently rectangular in transverse section, and there is usually a considerable development of collenchyma in the angles, and, in some species, elsewhere in the primary cortex. The arrangement of the collenchyma in the stem is of diagnostic value. A few members of the family, such as species of *Hedeoma*, have reduced leaves and assimilatory stems. Many species are densely covered with **hairs** of various kinds, one of the most characteristic being the short-stalked glands with heads of 1-16 or more cells. These secrete pleasantly scented oils, such as those of lavender, rosemary, thyme, peppermint, &c. Non-glandular hairs are also frequent, and may be uniseriate, tufted, or branched. The leaf is isobilateral or dorsiventral, and, in some species, the margins are strongly incurved. **Stomata** occur on one or both surfaces, and are commonly of the caryophyllaceous type, although often intermixed with others that are ranunculaceous. The vascular structure of the **petiole** is of taxonomic interest, and the structure, in transverse sections through the distal end, ranges from a simple, shallow arc of separate bundles, through forms with a continuous, more or less strongly curved arc, often with incurved ends, to a closed ring of bundles. The amount and seat of origin of the **cork** is very variable. In many species it arises in the subepidermis, but in others it is formed at deeper levels in the primary cortex, in the pericycle, the phloem, or occasionally in the xylem itself. Cork is sometimes formed by the direct suberization of parenchymatous cells without the preliminary activity of a phellogen. In the young stem, **xylem** and **phloem** are, in some species, confined to collateral bundles, which are especially well developed in the angles of the axis. In other species contiguous bundles are separated by interfascicular fibres, whilst, in a third category, the continuous xylem is traversed by narrow medullary rays. The vessels are usually small in diameter. **Crystals,** although not very frequent, occur in many forms, small needles, rods, and octahedra constituting the dominant types. **Hesperidin** is sometimes present.

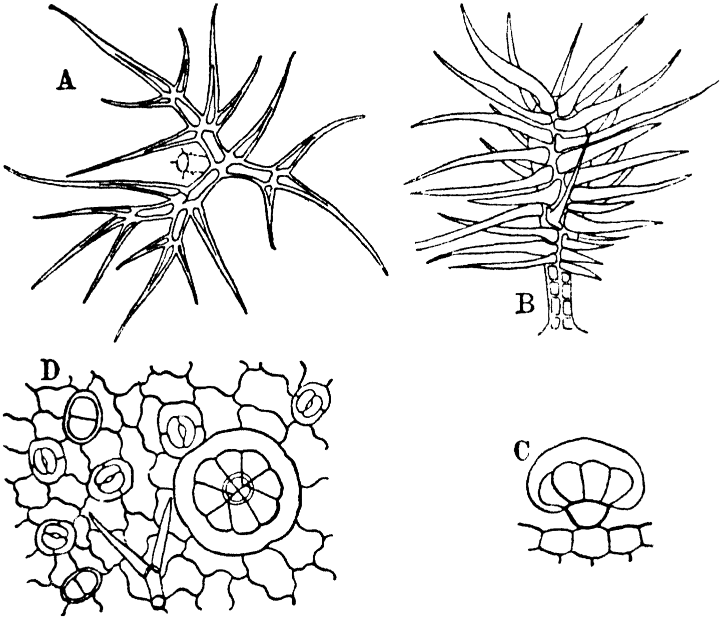


FIG. 249. *LABIATAE*

Hairy covering of the Labiatae: A, C, and D, *Lavandula vera* DC. B, *Stachys affinis* Fresen.—A, C, D by Solereder, B after Volkens.

(ii) WOOD

Vessels small to minute, typically in tangential bands, often with spiral thickening and semi-ring-porous, perforations simple, intervascular pitting alternate and small, pits to parenchyma similar, members of medium length to very short. **Parenchyma** paratracheal, rather sparse. **Rays** sometimes of

2 sizes, up to 4–12 cells wide, sometimes high, heterogeneous. **Fibres** with simple pits, reported to be septate in some genera, of medium length to extremely short.

LEAF

Isobilateral, dorsiventral, or centric (see also under 'Mesophyll'). **Hairs** very variable, but affording valuable characters for the identification of genera and species. The occurrence together of diverse kinds of clothing hairs and characteristic short-stalked glands with uni- or multicellular heads is characteristic of the whole family. Walls of the hairs stiff and lignified in many species, in others composed of cellulose but strongly cuticlarized.

A. Non-glandular hairs. (i) Uniseriate, of varying length, sometimes curved, commonly with swollen basal cells, or seated on pedestals of several epidermal cells, e.g. in *Galeopsis*, *Hedeoma*, *Lamium*, *Origanum*, *Stachys*. Bicellular trichomes with short basal and long terminal cells recorded in species of *Stachys*, *Westringia*, &c. (ii) Branched or tufted multicellular trichomes (Fig. 249 A–B) occur in *Ballota*, *Gomphostemma*, *Lavandula*, *Marrubium*, *Mentha*, *Nepeta*, *Phlomis*, *Rosmarinus*, *Sideritis*, *Stachys*, *Teucrium*, and other genera.

B. Glandular hairs (Fig. 249 C–D). The glands vary in the number of cells in the head, the length of the stalks, the amount of secretion accumulated beneath the cuticle and the degree to which sunk in the epidermis. The physiology and mode of secretion by the glands of *Plectranthus* have been studied by Kisser (1240). Several types of gland frequently occur together in a single leaf. The following particulars give some idea of their range of structure. (i) Heads unicellular, stalks up to 3 cells long, in species of *Lamium*, *Lavandula*, *Melissa*, *Mentha*, *Monarda*, *Ocimum*, *Pogostemon* (heads specially large), *Rosmarinus*, *Salvia*, *Satureia*, *Scutellaria*, *Thymus*. Similar but with longer stalks in species of *Ajuga*, *Horminum*, *Lophanthus*, *Salvia*, *Sideritis*. (ii) Heads bicellular. This type very common. Shortly stalked in species of *Dracocephalum*, *Elsholtzia*, *Hyssopus*, *Lavandula*, *Lophanthus*, *Nepeta*, *Perilla*, *Salvia*; similar but with longer stalks in species of *Ballota*, *Salvia*, *Scutellaria*, *Stachys*. (iii) Heads 4-celled; stalks short. This type very common, sometimes mixed with hairs having a larger number of cells in the head, recorded, for example, in species of *Ballota*, *Galeopsis*, *Lamium*, *Leonotis*, *Leucas*, *Marrubium*, *Nepeta*, *Salvia*, *Stachys*, *Teucrium*. (iv) Heads 8-celled; stalks usually very short; frequently sunk in pits. This type widespread in the family. Similar hairs but with longer stalks recorded in a few species of *Lavandula* and *Salvia*. (v) Heads of 16 or more cells; stalks short or long. This type relatively infrequent, recorded for example in species of *Galeopsis* and *Scutellaria*.

Leaf-teeth sometimes glandular. Cells of the **epidermis** occasionally papillose, e.g. according to Étienne (664) in species of *Bystropogon*; frequently convexly arched outwards. Epidermal cells in surface view described by Buch (302) as generally having more or less sinuous, anticlinal walls; polyhedral and with straight anticlinal walls in species of *Ajuga*, *Lavandula*, *Rosmarinus*, and *Thymus*. **Stomata** sometimes occurring on both surfaces, but more frequently restricted to the lower side; often caryophyllaceous (Fig. 249 D). Caryophyllaceous stomata noted in *Dysophylla*, a somewhat aberrant, aquatic genus with whorled leaves. Caryophyllaceous stomata also observed in the leaves of all of the numerous species examined by Buch (302), but sometimes accompanied by stomata conforming more to the ranunculaceous type. Ranunculaceous stomata also recorded by Holm (1019) in *Cunila mariana* Linn. **Hydathodes** recorded at the leaf margins in *Dysophylla* by Hülsbruch (1106). A **hypoderm** of large cells present below the upper epidermis in *Rosmarinus officinalis* Linn.

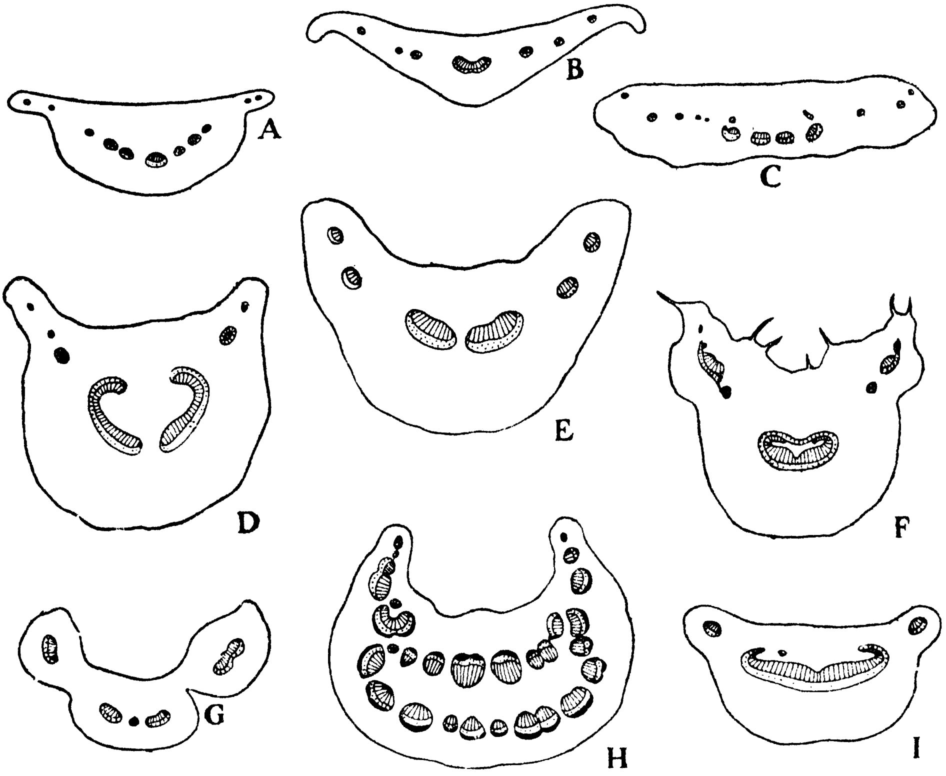


FIG. 250. *LABIATAE*

A, *Horminum pyrenaicum* Linn. Petiole ×8. B, *Physostegia virginiana* Benth. Petiole ×6. C, *Coleus comosus* Hochst. Petiole ×8. D, *Comanthosphace sublanceolata* Moore. Petiole ×15. E, *Lycopus europaeus* Linn. Petiole ×14. F, *Stachys betonica* Benth. Petiole ×11. G, *Lamium album* Linn. Petiole ×11. H, *Phlomis tuberosa* Linn. Petiole ×8. I, *Ballota rupestris* Vis. Petiole ×15.

Mesophyll consisting wholly of palisade cells in species of *Salvia* from the Canary Islands, according to Étienne (664); isobilateral in '*Lavandula bucheri* Webb. et Benth.'; centric in *Lavandula pinnata* Linn. f. Cells of the spongy mesophyll mostly orientated at right angles to the lower surface in a few species of *Bystropogon*, *Teucrium*, and *Thymus*. The type of mesophyll is stated by Buch (302) to be unreliable for diagnostic purposes owing to variations in response to environmental conditions. Vascular bundles of the **veins** accompanied by sclerenchyma in some species, especially in those showing xerophytic features; in others frequently surrounded by a parenchymatous sheath. Large bundles of fibres, besides those accompanying the vascular bundles, observed by Etienne (664) in the mesophyll of species of *Micromeria*. **Midrib** with a single vascular strand supported above and below by collenchyma in *Monarda* (Holm 1054); including 2 vascular bundles partly fused laterally in *Cunila* (Holm 1019); supplied by a circle of 5 collateral bundles with xylem towards the centre in *Collinsonia canadensis* Linn. (Holm 1033).

Petiole (Figs. 250 and 251 A, C, F, H), in transverse sections through the distal end of species examined at Kew, exhibiting a considerable range of vascular structure, often affording characters of taxonomic value. Vascular structure appearing as a simple, shallow to moderately deep arc of widely spaced bundles in species of *Coleus* (Fig. 250 C), *Horminum* (Fig. 250 A), *Micromeria*, *Monarda*, *Perovskia*, *Physostegia* (Fig. 250 B); median strand crescentic but continuous in species of *Ballota* (Fig. 250 I), *Dracocephalum*, *Lallemantia* (Fig. 251 F), *Lavandula*, *Melissa*, *Melittis*, *Nepeta*, *Origanum*. Main petiolar vascular strand in the form of a continuous arc with very much incurved ends or even tending to become cylindrical in species of *Leonurus*, *Phlomis*, *Stachys* (Fig. 250 F), and *Teucrium*; similar but with a dissected vascular arc in species of *Elsholtzia*, *Galeopsis*, *Plectranthus*; with an adaxially concave cylinder of numerous, separate bundles in *Phlomis tuberosa* Linn. (Fig. 250 H). Additional, subsidiary vascular bundles present in the petiolar wings in all of the species examined. A single broad bundle surrounded by thin-walled parenchyma and hypodermal collenchyma recorded in *Hedeoma* by Holm (1025).

Large, sac-like **secretory cells** in the mesophyll of *Brazoria* and *Physostegia* appear as transparent dots and striations in the leaf. Oil recorded by Mullan (1571) in *Leucas aspera* Link. **Crystals,** when present, excreted in the form of small needles, rods, or octahedra, often occurring in considerable numbers in one cell. Cluster crystals comparatively rare, recorded, according to Solereder, in species of *Lycopus*, *Pycnanthemum*, *Salvia*, and noted by Etienne (664) in *Lavandula pinnata* Linn. f. and '*L. buchii* Webb. et Benth.', but these and ordinary solitary crystals said to be more frequent in the floral organs. Crystalliferous sclerenchyma recorded by Solereder (2160) in the lowest part of the leaf in 'Folia Salviae'. **Scutellarin** is said to occur in the epidermis, especially on the abaxial surface of the leaf, in all examined species of *Scutellaria* as well as in *Galeopsis tetrahit* Linn. and *Teucrium chamaedrys* Linn. Tests for this substance in species of *Ballota*, *Lamium*, *Leonurus*, *Mentha*, *Nepeta*, *Prunella*, *Teucrium* (excluding the species named above), and *Thymus* were, according to Solereder, negative. Scutellarin is deposited in the form of tufts, stellate clusters of sphaerites, or needle-shaped crystals in sections treated with 10 per cent. hydrochloric acid. Some authors refer to the occurrence of **hesperidin** crystals in certain members of the family, but, according to Buch (302), their presence is inconstant.

The **developmental anatomy** of the leaf of *Plectranthus* has been studied by Schwarz (2059).

AXIS

STEM (Fig. 251 B, D, E, G, I, J)

Cuticle often thick, especially in xerophytes, e.g. in species of *Lavandula*, *Micromeria*, and *Thymus* from the Canary Islands examined by Etienne (664). A papillose **epidermis** noted by the same author in species of *Lavandula* and

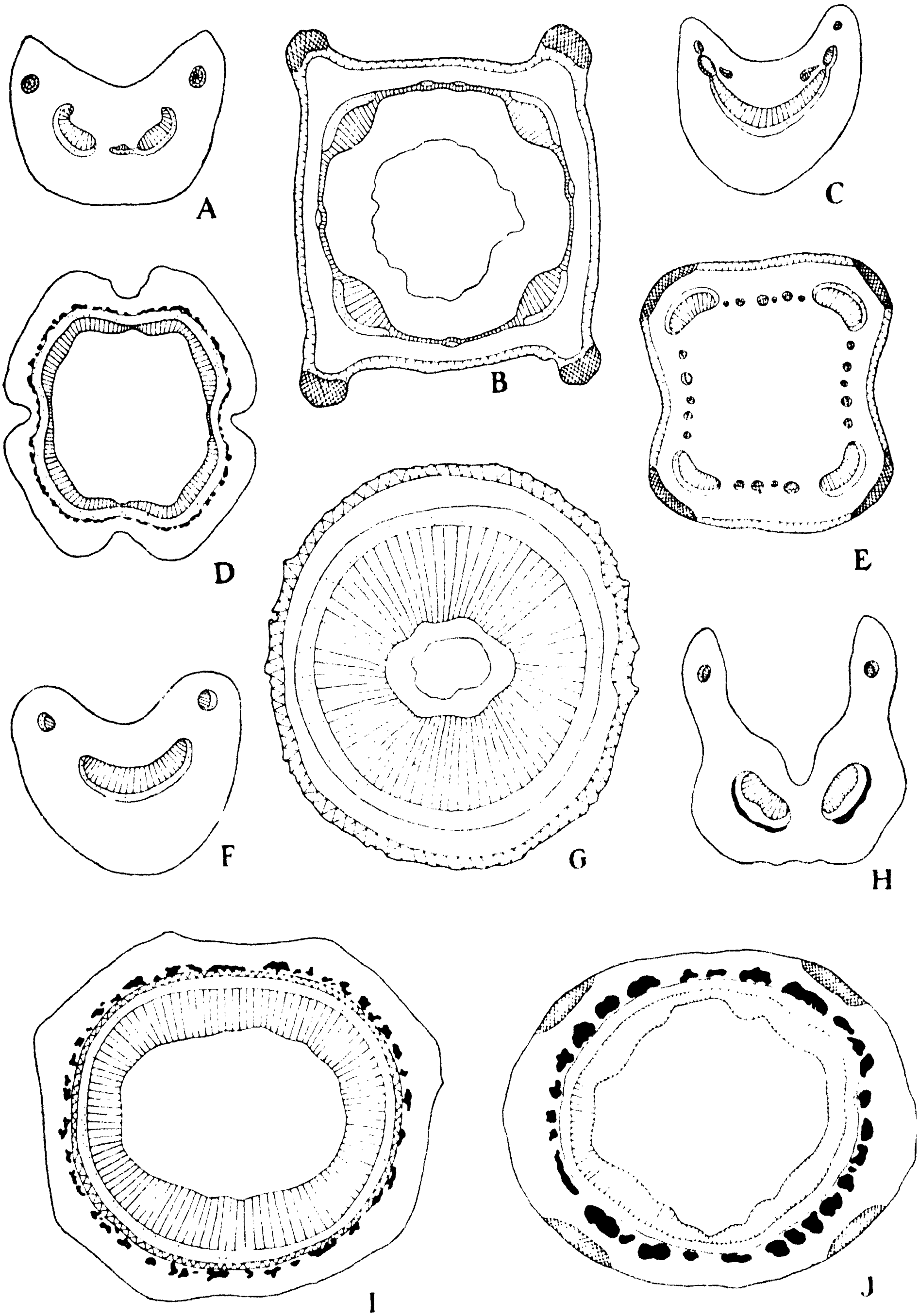


FIG. 251. *LABIATAE*

A, *Galeopsis tetrahit* Linn. Petiole × 15. B, *Glechoma hederacea* Linn. Stem × 19. C, *Monarda* sp. Petiole × 19. D, *Elsholtzia stauntonii* Benth. Young stem × 13. E, *Physostegia virginiana* Benth. Stem × 8. F, *Lallemantia canescens* Fisch. et Mey. Petiole × 19. G, *Sideritis scordioides* Linn. Stem × 19. H, *Marrubium vulgare* Linn. Petiole × 26. I, *Elsholtzia stauntonii* Benth. Stem × 13. J, *Perovskia atriplicifolia* Benth. Young stem × 19.

Thymus. Stems in many genera and species quadrangular in transverse section (Fig. 251 B, E), with well-defined groups of collenchyma in the 4 angles. Amongst non-European genera this structure was noted by Lemesle (1349) in species of *Acanthomintha*, *Cedronella*, *Ceranthera*, *Orthosiphon*, and *Poliomintha*. Sub-epidermal collenchyma noted by the same author in *Eriope*, *Meriandra*, *Perilomia*, *Zataria*, and a large group of collenchyma against each of the 6 sides of the stem in *Pycnostachys reticulata* Benth. Small groups of collenchyma occur between those in the corners, e.g. in species of *Anisomeles*, *Dysophylla*, *Horminum*, *Hoslandia*, *Lasiocorys*, *Leonurus*, *Lycopus*, *Marsupianthus*. A closed ring of collenchyma in the primary cortex recorded in species of *Aeolanthus*, *Anisochilus*, *Chelonopsis*, *Coleus*, *Colquhounia*, *Craniotome*, *Phyllostegia*, *Plectranthus*, *Pogostemon*. Some of the collenchyma cells replaced by sclerotic cells or groups of fibres in *Bystropogon*, *Gardoquia*, *Hymenocrater*, *Keithia*, *Monarda*, *Prasium*, *Salazaria*, *Salvia*. Isolated strands of fibres present on the inside of the collenchyma in *Cunila galioides* Benth. Collenchyma absent from the cortex in species of *Cuminia*, *Hemiandra*, *Hemigenia*, *Prostanthera*, *Westringia*. Lemesle has also recorded thin-walled, lignified cells in the **cortex** of *Anisochilus* and *Geniosporum*; thick-walled sclerotic cells in the corresponding position in *Eriope* and *Keithia*; thin- and thick-walled, lignified elements united to form a complete ring in *Gardoquia*. Other features of the primary cortex are characteristic of particular genera and species and include items such as palisade tissue in *Lavandula* and other genera; a hypodermal layer of lignified cells in *Prasium*; large intercellular spaces in *Prunella* and *Stachys*. Primary cortex of *Dysophylla verticillata* Benth. including a well-developed system of intercellular spaces, with, according to Hülsbruch (1106), short glandular hairs projecting from the surrounding cells into some of the intercellular cavities. Short glandular hairs stated by the same author to be specially numerous in specimens cultivated under water.

Cork often scanty, but well developed in certain genera and species. Cork recorded by various authors or observed at Kew arising in the sub-epidermal region in species of *Aeolanthus*, *Anisochilus*, *Cedronella*, *Coleus*, *Eriope*, *Hemiandra*, *Hyssopus*, *Leonotis*, *Leonurus*, *Plectranthus*, *Pogostemon*, *Pycnostachys*, *Salvia*, *Sideritis* (Fig. 251 G) (sometimes becoming lamellated owing to the development of successive cork zones), *Stachys*, and *Tinnea*. Cork formed at deeper levels in the primary cortex in species of *Hyssopus*, *Lasiocorys*, *Lavandula*, *Perilomia*, and *Sideritis*. Cork arising in the pericycle in species of *Ballota*, *Bystropogon*, *Elsholtzia* (Fig. 251 I), *Gardoquia*, *Lavandula*, *Leonotis*, *Micromeria*, *Monarda*, *Origanum*, *Perovskia*, *Plectranthus*, *Prasium*, *Rosmarinus*, *Salvia*, *Satureia*, *Sideritis*, *Sphacele*, *Stachys*, *Teucrium*, *Thymus*. First cork formed in the pericycle, but later developing in the secondary phloem, in species of *Meriandra* and *Poliomintha* according to Lemesle (1350). Successive zones of cork also reported by the same author (1347) to arise at progressively deeper levels, including the phloem, in stems of various strongly xerophytic species of *Salvia*. The same author subsequently (1348, 1350) observed early cork formation in the pericycle and late cork formation in the xylem in *Hymenocrater bituminosus* Fisch. et Mey. and *H. calycinus* Benth., the first of which is a shrubby species from Persia. Lemesle suggests that the cork zones are formed during intensely dry periods. The cork in certain species of *Origanum*, *Satureia*, *Thymus* arises, according to Solereder, by the gradual suberization of cells on the inside of the endodermis without any previous phellogen activity. The same mode of cork formation also recorded in the species of *Hymenocrater* examined by Lemesle. Successive zones of cork and phloem fibres reported by Solereder to occur in *Salvia aegyptiaca* Linn. Cork described by Lemesle (1350) as arising from a sinuous phellogen and engulfing some of the sclerenchymatous elements of the pericycle, in *Keithia*, a type of structure previously reported to occur in *Rosmarinus*.

An **endodermis** of thin-walled cells often differentiated. Endodermis composed of large cells with completely suberized walls in species of *Bystropogon*, *Cedronella*, *Micromeria*, and *Thymus* from the Canary Islands examined by Etienne (664); a completely suberized endodermis also noted by Lemesle (1350) in *Acanthomintha*, *Cedronella*, *Ceranthera*, *Chelonopsis*, *Colquhounia*, *Craniotome*, *Cunila*, *Dysophylla*, *Keithia*, *Perilomia*, *Zataria*. Radial walls suberized in *Marsypianthus* and *Soliera* according to Lemesle, who has also described the endodermal cells as large but not suberized in *Orthosiphon*. Casparian thickenings noted by Mullan (1571) in *Leucas aspera* Link. and observed at Kew in species of *Ballota*, *Galeopsis*, *Prunella*, *Scutellaria*, and *Stachys*.

Pericycle usually containing relatively little sclerenchyma, the latter, when present, commonly in strands (Fig. 251 I, J), sometimes reniform in transverse section, a phloem group of the vascular system being situated in the concavity. Lemesle (1349) has recorded the following information concerning the pericyclic fibres. (A) In species with the endodermis differentiated: Absent from species of *Acanthomintha*, *Ceranthera*, *Soliera*, *Zataria*; occurring as isolated elements or small groups in *Chelonopsis*, *Craniotome*, *Cunila*, *Dysophylla*; forming arcs on the same radii as the angles of the stem in *Cedronella*, *Marsypianthus*, *Orthosiphon*; numerous in *Periloma*; arranged in large groups in *Colquhounia*. (B) In species with no well-defined endodermis: Absent from *Gardoquia*, but generally present in other genera and species examined; in closely placed groups in *Hemiandra*, *Hoslundia*, *Meriandra*, *Pycnostachys*; forming composite continuous rings in *Eriope* and *Geniospermum*. A continuous ring of pericyclic sclerenchyma recorded by Solereder in species of *Ajuga*, *Cymaria*, *Marrubium*. Large strands of pericyclic fibres noted by Etienne (664) on the same radii as the angles of the stem in species of *Cedronella*, *Lavandula*, and *Salvia* and in *Hymenocrater* by Lemesle (1348). Pericycle in *Teucrium heterophyllum* L'Hér., a species from exposed, arid habitats, bounded externally by arcs of fibres separated, by thin-walled partially sclerosed cells, from an inner circle of cells with pitted, thickened walls. Separate strands of pericyclic fibres also noted by Holm (1054) in *Monarda*. Rather small, separate bundles of fibres in the pericycle noted at Kew in species of *Ballota*, *Cedronella*, *Coleus*, *Dracocephalum*, *Elsholtzia*, *Hyssopus*, *Lavandula*, *Leonurus*, *Lycopus*, *Marrubium*, *Melissa*, *Melittis*, *Nepeta*, *Perovskia*, *Phlomis*, *Physostegia*, *Plectranthus*, *Prostanthera*, *Salvia*, *Satureia*, *Sideritis*, *Stachys*, *Teucrium*. Pericyclic fibres seen to be absent from species of *Comanthosphace*, *Galeopsis*, *Horminum*, *Lallemantia*, *Lamium*, *Mentha*, *Micromeria*, *Monarda*, *Prunella*, *Thymus*.

The **phloem** groups of the 4 large vascular bundles opposite the 4 angles of the stem are occasionally connected to one another by sclerenchymatous elements, e.g. in species of *Hyssopus*, *Ocimum*, *Phyllostegia*. Masses of elongated, sclerosed cells noted by Etienne (664) in the secondary phloem of *Salvia broussonetii* Benth. and fibres by Lemesle (1349) in *Cunila*, *Hoslundia*, *Meriandra*, *Salazaria*, *Tinnea*. Phloem fibres forming a continuous ring in old stems of *Hemiandra*.

Vascular bundles stated by Briquet and others, as cited by Solereder, to pursue the following course. 'From each leaf two vascular bundles usually enter the stem, where, diverging from one another, they pass down through the next internode in the two angles of the stem situated on the right and left of the leaf. In the next internode they run beside the leaf trace bundles entering the stem at the second node, and fuse with them at the following (third) node.'

Xylem forming a continuous cylinder at a very early stage in most of the genera and species examined at Kew (except *Horminum pyrenaicum* Linn. and *Physostegia virginiana* Benth. (Fig. 251 E)), usually owing to the development of interfascicular fibres between the xylem groups of contiguous bundles. Xylem in the form of a continuous cylinder also noted by Étienne (664) in species of *Bystropogon*, *Lavandula*, *Micromeria* (all species examined), *Sideritis*, *Teucrium*, *Thymus*. Xylem and phloem stated, by the same author, to be discontinuous in other species endemic to the Canary Islands, the contiguous xylem groups of the bundles being separated from one another by interfascicular sclerenchyma. Groundwork of the xylem commonly composed of thick-walled fibres, the vessels being scattered and comparatively infrequent. Broad, concentric zones of thick-walled fibres and infrequent vessels, alternating with narrower zones including more numerous vessels and less strongly thickened fibres (corresponding to periods of drought and relatively high rainfall, respectively), noted by Etienne (664) in a few species of *Micromeria*. Four primary vascular bundles with secondary strands between them present in some herbaceous species, e.g. recorded by Holm (1044) in *Nepeta*. The following arrangements of xylem and phloem were noted by Lemesle (1349). Four large vascular bundles in the angles of the stem separated from one another by sclerenchyma with small secondary vascular strands embedded in it in *Aeolanthus*, *Anisochilus*, *Anisomeles*, *Cedronella*, *Chelonopsis*, *Colquhounia*, *Craniotome*, *Dysophylla*, *Eriope*, *Geniosporum*, *Hoslundia*, *Marsypianthus*, *Orthosiphon*. Xylem continuous in all of the other, mostly rather woody, species examined by the same author. True interfascicular cambium present only in the basal portion of the first internode near the surface of the soil in *Collinsonia canadensis* Linn. according to Holm (1033). Old stems of *Thymus vulgaris* Linn. from the Pyrenees, stated by Solereder to exhibit eccentric growth in thickness, with subsequent formation of new strands of xylem in the secondary phloem. Vessels usually with simple perforations; rare perforation plates of an unusual type also recorded (see 'Wood'). **Pith** commonly homogeneous; frequently becoming hollow in herbaceous species. Pith of most of the species endemic to the Canary Islands examined by Etienne (664) described as persistent and becoming sclerified. Large groups of isodiametric, sclerotic cells embedded in the mainly unlignified pith recorded by the same author in *Salvia broussonetii* Benth. Pith becoming lignified in *Leucas aspera* Link. according to Mullan (1571); described by Lemesle (1349) as consisting of cells with cellulose walls in species of *Acanthomintha*, *Aeolanthus*, *Poliomintha*; including some sclerosed cells in *Anisochilus*; peripheral part lignified in *Anisochilus*, *Anisomeles*, *Geniosporum*, and *Meriandra*; wholly lignified and sometimes very small in diameter in the remaining genera and species examined by Lemesle.

Crystals of the same type as those described under 'Leaf' on p. 1045. Sphaero-crystals, believed to consist of hesperidin, recorded in the phloem of *Mentha piperita* Linn. by Kudelka (1291), and observed at Kew in a few species of *Hyssopus*, *Mentha*, and *Monarda*.

WOOD (Fig. 254 A–D and F–G)

Vessels small (mean tangential diameter less than 100 μ), sometimes extremely small (less than 25 μ), e.g. in *Phlomis* and *Rosmarinus*; typically in numerous small multiples and groups that are arranged in tangential lines (Fig. 254 A), but with the vessels mostly solitary in *Hoslundia* and without any very distinct tangential lines in *Hoslundia* or *Leucosceptrum*; these bands sometimes include a large number of minute, tracheid-like vessels, e.g. in *Lavandula* and *Salvia*; about 15 per sq. mm. in *Hoslundia* and *Leucosceptrum*, 40 to over 100 per sq. mm. in the other genera examined; semi-ring-porous in *Lavandula*, *Phlomis*, *Rosmarinus*, and *Salvia*; spiral thickening observed in *Lavandula*, *Rosmarinus*, and *Salvia*, and reported by Solereder, chiefly in the narrower vessels, in *Prasium*, *Prostanthera*, *Sideritis*, *Teucrium*, *Thymus*, and *Westringia*. Perforations exclusively simple; Solereder, however, notes the occurrence of some scalariform plates, with the bars at right angles to their usual direction, in *Cymaria elongata* Benth. Intervascular pitting alternate and small, except in *Hoslundia*; pits to ray and wood parenchyma similar, commonly unilaterally compound in *Phlomis*. Mean member length 0·24 mm. in *Salvia*, and 0·5 mm. in *Leucosceptrum*. **Parenchyma** paratracheal and rather sparse to very sparse, e.g. in *Phlomis fruticosa* Linn.; most commonly as scattered cells that, together with the vessels, form tangential bands (Fig. 254 A); sometimes as narrow sheaths round the vessels, e.g. in *Hoslundia* and *Leucosceptrum* (Fig. 254 B); strands most commonly of 4 cells, sometimes up to 8 cells in *Leucosceptrum*. **Rays** sometimes of 2 distinct sizes, e.g. in *Lavandula* and *Salvia*; the larger rays in the material examined typically not less than 4 cells wide and up to 10 or more cells wide in some species of *Lavandula* and *Salvia*, but Solereder states that for the whole family the rays are mostly narrow; rays up to more than 1 mm. high in *Hoslundia*, *Lavandula*, and *Salvia*; uniseriate rays numerous, usually composed of upright cells, but occasionally with a few square cells; aggregate rays present in *Salvia mellifera* Greene, the large rays apparently breaking up into smaller units, 8–16 rays per mm.; heterogeneous (Kribs's Type II A) with 4 or more marginal rows of square or upright cells occurring occasionally, except in *Phlomis*. Solereder states that the rays are commonly composed entirely of square or upright cells, but this character was observed only in *Hoslundia*; sheath cells present in *Lavandula*, *Leucosceptrum*, *Phlomis*, and *Salvia*, but seldom completely enclosing the rays. Crystals not observed. **Fibres** with numerous, very small, simple pits on the radial walls. Solereder quotes Born as noting septate fibres in some species of *Coleus*, *Gomphostemma*, *Hyptis*, *Lavandula*, *Phyllostegia*, *Plectranthus*, *Pogostemon*, and *Prasium*; walls tending to be thick; mean length 1·1 mm. in *Leucosceptrum* and 0·35 mm. in *Salvia*.

STOLONS

The anatomy of the stolons of *Lamium album* Linn. and *Teucrium chamaedrys* Linn. has been described by Chaillot (346).

ROOT

Primary vascular structure tetrarch to pentarch in *Mentha piperita* Linn., large air canals being present in the **cortex** of the same species according to Kudelka (1291). Large spherical **crystals** recorded by Holm (1044) in the cortex of *Glechoma hederacea* Linn. (syn. *Nepeta glechoma* Benth.) when preserved in alcohol, but not in fresh material.

ECOLOGICAL ANATOMY

The anatomy of the aquatic genus *Dysophylla* has been described from the ecological standpoint by Hülsbruch (1106) (see 'Cortex' on p. 1047). Differences between submerged and aerial leaves of *Preslia cervina* Fresen., *Mentha aquatica* Linn., *Scutellaria hastifolia* Linn., and *Stachys palustris* Linn. also described by the same author. These differences consist mainly of variations in the shape and arrangement of the mesophyll cells, in the development of intercellular spaces, in the distribution of stomata and hairs, and the extent to which the xylem and mechanical elements are developed.

ECONOMIC USES

Many members of the family are cultivated for ornamental purposes and for the sake of their fragrance, which is due to essential oils secreted from the various kinds of glandular hairs with which the plants are usually clothed. Many species were at one time, and some still are, prized as culinary herbs. These include sage (*Salvia officinalis* Linn.), mint (*Mentha* spp.), thyme (*Thymus vulgaris* Linn.), marjoram (*Origanum marjorana* Linn.). It is noteworthy that commercial samples of dried marjoram grossly adulterated with the leaves of a species of *Cistus* (the latter recognizable by the abundant stellate hairs on the leaves) have been submitted to Kew for examination. Samples of dried mint adulterated with the leaves of *Ailanthus altissima* Swingle (*A. glandulosa* Desf.) (Family Simarubaceae) have also been met with from time to time. For diagnostic microscopical characters of this species see p. 325.

Lavender, which is important in perfumery, consists mainly of cultivated varieties of *Lavandula vera* DC., although the oil is also distilled from *L. spica* Cav. and possibly other species of *Lavandula* in southern Europe. Other members of the family used in perfumery include rosemary (*Rosmarinus officinalis* Linn.), peppermint (*Mentha piperita* Linn.), and patchouli (*Pogostemon heyneanus* Benth.), the last being an Indian plant. According to some authorities patchouli is frequently adulterated with other members of the Labiatae such as species of *Hyptis* and *Ocimum*. The tubers of the so-called Chinese artichoke (*Stachys sieboldi* Miq.) are edible. Beverages have been prepared locally from various species, notably the so-called 'bush tea' of Queensland prepared from the leaves of *Ocimum sanctum* Linn.

Medicinal properties of various kinds have been attributed to quite a number of species, but most of these are not now regarded as important in medical practice, although used as herbal remedies. *Salvia officinalis*, still occasionally used in medicine, is characterized microscopically by very numerous, narrow, uniseriate, 2- to 6-celled hairs with thick walls; small glands with 1- or 2-celled heads; larger glands with unicellular stalks; caryophyllaceous stomata. Solereder (2160) has recorded the occurrence of large, crystalliferous, sclerenchymatous elements in the lower part of the base of the leaf of this species. North American species with reputed medicinal properties include *Collinsonia canadensis* Linn., *Cunila mariana* Linn., *Glechoma hederacea* Linn. (syn. *Nepeta glechoma* Benth.), *Hedeoma pulegioides* Pers., and *Monarda punctata* Linn.; the microscopical structure of all of these has been described by Holm (1019, 1025, 1033, 1044, 1054). Zornig and Buch (2510) have described the structure of the leaves of 54, mainly European, species from 28 genera of Labiatae which have at one time or another been used for medicinal purposes. These authors concluded that all of these species can be identified by the structure of the hairs and glands, the distribution of sclerenchyma, and the occurrence of calcium oxalate crystals. These conclusions are very similar to those published a year earlier by Buch (302) in a thesis. The structure of the hairs in about 20 species of Labiatae with reputed medicinal properties has also been published by Small (2131), who formed the opinion that all of these species could be recognized by the structure of their hairs alone.

The microscopy of the leaves of a species of *Orthosiphon* with alleged medicinal properties has been described by Tunman (2290). Small microscopical differences between the leaves of *Thymus vulgaris* and those of *T. serpyllum* Linn. have been recorded by Edman (623). The non-glandular hairs are more frequently bent in *T. vulgaris* than in *T. serpyllum*, whilst the marginal hairs of the last species are said to be absent from the former. In *T. serpyllum* the cuticle is more definitely striated than in *T. vulgaris*.

Youngken (2490) has recorded an instance in which *Ballota hirsuta* Benth. was present as an adulterant in Hoarhound (*Marrubium vulgare* Linn.) shipped from a Greek port to the U.S.A. The presence of *Ballota hirsuta* could be detected, amongst other characters, by the presence of branched trichomes of which the central branch terminated in a glandular head of 1–4 cells. No such hairs occur in *Marrubium vulgare*. The microscopical structure of species of *Thymus*, *Monarda*, and *Ocimum* which yield thymol has been described by Blaque (204).

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Acanthomintha, Aeolanthus, Ajuga, Anisochilus, Anisomeles, Ballota,* Brazoria, Bystropogon, Cedronella,* Ceranthera, Chelonopsis, Coleus,* Collinsonia, Colquhounia, Comanthosphace,* Craniotome, Cuminia, Cunila, Cymaria, Dracocephalum,* Dysophylla, Elsholtzia,* Eriope, Galeopsis,* Gardoquia, Geniosporum, Gomphostemma, Hedeoma, Hemiandra, Hemigenia, Horminum,* Hoslundia, Hymenocrater, Hyssopus,* Keithia, Lallemantia,* Lamium,* Lasiocorys, Lavandula,* Leonotis, Leonurus,* Leucas, Lophanthus, Lycopus,* Marrubium,* Marsypianthus, Melissa,* Melittis,* Mentha,* Meriandra, Micromeria,* Monarda,* Nepeta,* Ocimum, Origanum,* Orthosiphon, Perilla, Periloma, Perovskia,* Phlomis,* Phyllostegia, Physostegia,* Plectranthus,* Pogostemon, Poliomintha, Prasium, Preslia, Prostanthera,* Prunella,* Pycnanthemum, Pycnostachys, Rosmarinus, Salazaria, Salvia,* Satureia,* Scutellaria,* Sideritis,* Soliera, Sphacele, Stachys,* Teucrium,* Thymus,* Tinnea, Westringia, Zataria.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

The above description is based primarily on material of Hoslundia, Lavandula, Leucosceptrum, Phlomis, Rosmarinus, and Salvia, but note has been taken of the details given by Solereder for the following additional genera: Coleus, Gomphostemma, Hyptis, Monarda, Phyllostegia, Plectranthus, Pogostemon, Prasium, Prostanthera, Sideritis, Teucrium, Thymus, and Westringia.

LITERATURE

(i) *On General Anatomy*

Blaque **204**, Brunswick **297**, Buch **302**, Chaillot **346**, Edman **623**, Etienne **664**, Ewing and Clevenger **668**, Holm **1019**, **1025**, **1033**, **1044**, **1054**, Hülsbruch **1106**, Kisser **1240**, Klug **1247**, Kudelka **1291**, Lemesle **1347–50**, Lièvre **1371**, Mullan **1571**, Sayeedud-Din **2006**, Schwarz **2059**, Sinnott and Bloch **2118**, Small **2131**, Solereder **2160**, Tunman **2290**, Youngken **2490**, Zornig and Buch **2510**.

(ii) *On Wood Structure*

Greguss **2522**.

210. PLANTAGINACEAE

(FIG. 253 on p. 1054; FIG. 254 on p. 1058; FIG. 256 on p. 1062)

SUMMARY

A small, widely distributed family. Many species of *Plantago* are herbs with a basal rosette of leaves, but others are more woody and have the form of small shrubs. *Littorella uniflora* (L.) Aschers has a somewhat variable habit depending on whether it grows in marshy ground or immersed in water. The land form has a basal rosette of flattened leaves, whilst the aquatic form has longer, erect, cylindrical leaves. The general morphology of the family has been fully described by Pilger (1725). One of the most interesting anatomical features of *Plantago* is the occurrence, in certain species, of **cambiform rows of cells** in the cortex and/or pith of the axis. These structures appear to represent incompletely developed vascular bundles. In some instances transitions between them and true **medullary bundles** are known to occur. In the more shrubby members of the family the wood consists almost entirely of vessels and fibres. **Vessels** very small, in radial lines, perforations simple, intervascular pitting alternate, members moderately short. **Parenchyma** absent or extremely sparse. **Rays** absent. **Fibres** with simple pits. The primary **cortex** of *Littorella* contains a well-developed system of intercellular spaces.

LEAF

(i) PLANTAGO

Isobilateral, dorsiventral or with the mesophyll wholly composed of palisade cells according to the species. Isobilateral in *P. indica* Linn., *P. lanceolata* Linn., and *P. psyllium* Linn.; dorsiventral, e.g. according to Fuchs

(731) and Fischer (686), in *P. major* Linn. and *P. media* Linn. Mesophyll of *P. fernandezia* Bert. described by Brattsten (263) as consisting, at the base of the leaf, of an almost homogeneous spongy tissue surrounded by hypoderm, or, a little nearer the distal end, by adaxial hypoderm and abaxial collenchyma. Still nearer the distal end, in the same species, the collenchyma occurs only in association with the vascular bundles, palisade tissue being sufficiently developed in the distal half of the leaf for the structure to be described as dorsiventral. Mesophyll of *P. pachyphylla* Gray consisting wholly of spongy tissue, palisade cells being absent. Surface ranging from glabrous in some species to being covered with a dense, woolly indumentum. **Hairs** (Fig. 253 A–B) including capitate glands and non-glandular types. Many hairs uniseriate, but varying in the number, length, and mode of connexion of the component cells, as well as in the thickness of the wall and width of the lumen. Uniseriate hairs each with a short stalk cell and a long, thick-walled, flagelliform, terminal cell occur in the perennial species of *Plantago* belonging to the section *Oreades*, and in the sections *Arnoglossum* and *Leucopsyllium*. The contiguous walls of adjacent cells in some of the trichomes in *P. lanceolata* (but not in *P. major* or *P. media*), and to a greater extent in *P. cylindrica* Forsk. (Fig. 253 B) and *P. ovata* Forsk., dovetailed into one another. Uniseriate hairs with exceptionally large basal cells recorded in *P. triandra* Berggren by Betts (190). Glandular hairs with long or short stalks present in all of the species examined by Fischer (686) and observed by Brattsten (263) in *P. fernandezia* and *P. pachyphylla*. **Stomata** present on both surfaces in *P. indica*, *P. lanceolata*, *P. major*, *P. media*, and *P. psyllium*, according to Fuchs (731) and Fischer (686); absent from the upper surface in *P. fernandezia* and *P. pachyphylla* according to Brattsten (263); usually caryophyllaceous in *P. indica*, *P. lanceolata*, and *P. psyllium*, frequently so in *P. media* but rarely in *P. major*, the stomata in *P. media* mostly surrounded by 3 and in *P. major*

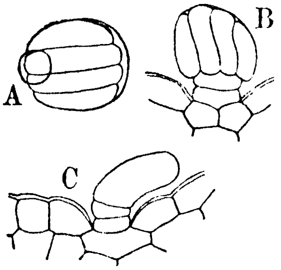


FIG. 252. *MYOPORACEAE*
Glandular hairs of *Myoporum acuminatum* R. Br.: A, Surface-view; B and C, Appearance in transverse section.—By Solereder.

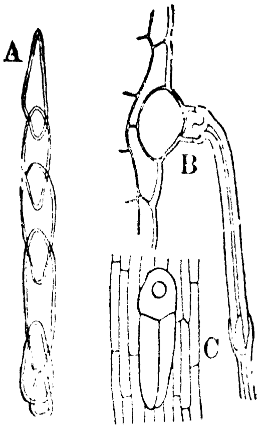


FIG. 253. *PLANTAGINACEAE*
Trichomes of the Plantagineae. A, *Plantago argentea* Chaix.; B, *P. cylindrica* Forsk.; C, *Littorella uniflora* (L.) Aschers.—A after Cugini, B–C by Solereder.

by 3–4 epidermal cells. **Hydathodes,** more numerous on the upper than on the lower surface of the leaf, recorded in *P. triandra* by Betts (190).

Vascular bundles of the **veins** in *P. psyllium* and allied species either supported above and below or entirely surrounded by sclerenchyma; the latter said by Pilger (1725) to be unlignified. Vascular bundles accompanied by collenchyma in at least certain species of *Plantago* according to Fischer (686), an **endodermis** with casparian thickenings surrounding the whole strand whether supported by sclerenchyma or not. An endodermis observed by Trapp (2275) in 8 species of *Plantago*, its distribution varying in different species. Endodermis accompanying the vascular bundles to within a short distance of the apex in some instances; found only in association with the midrib and primary lateral veins, and frequently incomplete, in others. Endodermal cells at first provided with casparian thickenings, but secondarily becoming suberized internally. Experiments led Trapp to conclude that 'the possession of a foliar endodermis is a character which is neither beneficial nor prejudicial to the physiological economy of the leaf'. From the phylogenetic standpoint the endodermis may be regarded as a primitive structure which is gradually disappearing through lack of function.

Variations in the vascular structure of the **petiole** provide features of specific diagnostic value. Vascular bundles widely spaced in all examined species, arranged in an arc composed of alternate large and small components. Each bundle, in species with large leaves, is itself arc-shaped.

For further interspecific differences see Oehm (1632) and Fuchs (731).

(ii) LITTORELLA UNIFLORA (L.) ASCHERS (Syn. *L. lacustris* Linn.)

Glandular **hairs** present (Fig. 253 C), each consisting of a very short basal cell bearing an eccentrically and horizontally placed, trowel-shaped head. Non-glandular hairs said to be absent. **Epidermis** composed of narrow, axially elongated, 4-sided cells. **Stomata,** in terrestrial forms, arranged in longitudinal rows on both surfaces of the leaf; rare in aquatic forms; tending to be caryophyllaceous. Aquatic leaves circular in transverse section. Subepidermal parenchyma more palisade-like in leaves of terrestrial forms of the plant. **Mesophyll** traversed by 3 vascular bundles, each surrounded by an (endodermal) sheath of cells, and consisting beneath the epidermis of 1 or 2 dense layers of cells containing abundant chlorophyll, the inner part being composed of a network of cells with less chlorophyll; typical palisade tissue absent. Polygonal **air cavities,** irregularly arranged around the centre of the transverse section, are separated from one another by single layers of parenchymatous cells.

Axis

(i) PLANTAGO

Stem and Rhizome (Fig. 256 F)

Cork in rhizomes often arising superficially, but frequently not well developed; only a very thin periderm, formed from the sub-epidermal layer, present in *P. atrata* Hoppe, *P. major* Linn., and *P. media* Linn. according to Pilger (1725). The outer layer of cortical cells alone becomes suberized in *P. lanceolata* Linn. or the cell walls are thickened but not suberized. A definite zone of bark, which peels off in layers, is formed in *P. alpina* Linn. from superficial followed by more deeply seated phellogens; scaly bark present in *P. maritima* Linn. No periderm produced in annual species belonging to the section *Psyllium*, the exterior being protected by an epidermis of cells with strongly thickened walls. True cork also absent from perennial species such as *Plantago cynops* Linn. but a zone of very large, rectangular cells with slightly thickened walls noted at Kew in a fairly deep position in the cortex of this species. Primary **cortex** often consisting of round, thin-walled cells forming a rather spongy tissue; 2 concentric zones of small cells separated by a zone of thickened cells noted in *P. cynops* (Fig. 256 F). True fibres unknown in the cortex of any species. **Endodermis** with casparian thickenings noted in *P. cynops*. **Pericycle** also often devoid of sclerenchymatous elements, but a few isolated fibres in this region noted at Kew in *P. cynops*. Walls of the cells at the boundary between the primary cortex and the **phloem** of *P. atrata*, *P. major*, and *P. media* said by Pilger (1725) to become thickened but not lignified. Secondary phloem strongly developed in species with thick rhizomes; consisting of elongated parenchymatous cells interspersed with very similar-looking groups of sieve tubes, the whole tissue being continuous on the outside with, and not clearly demarcated from, the round-celled tissue of the primary cortex.

Bundles of **cambiform tissue,** each consisting of long narrow cells containing abundant protoplasm, but apparently devoid of sieve tubes, frequent in the cortex and pith, particularly in fleshy rhizomes of many species, especially those belonging to the section *Polyneuron*, but by no means confined to this group. The cambiform strands said to be connected with one another but not with the bundles of the vascular ring. They are, nevertheless, reported to become converted into **medullary vascular bundles** in strong root-stocks of *Plantago major* and *P. media*. Structures transitional between the cambiform tissue and true vascular bundles also stated to occur in *P. cornuti* Gouan.

Vascular bundles in the fleshy rhizome of *P. major*, *P. media*, and *P. lanceolata* stated by Pilger (1725) to be separated by broad strips of parenchyma, parenchymatous cells also being abundant in the xylem itself. Cells of the xylem parenchyma in *P. major* short, provided with straight transverse walls; those of *P. media* and *P. lanceolata* longer, with oblique transverse walls. A continuous xylem ring present in rhizomes of species belonging to the section *Psyllium* as well as in the aerial stems of semi-shrubby species in the section *Leucopsyllium*. A xylem ring also recorded in annual species such as *Plantago indica* L. and by Brattsten (263) in *P. fernandezia* Bert. Ground-tissue of the xylem usually unlignified in herbaceous species. Xylem in the woody *P. cynops* composed of vessels which tend to be in radial rows and provided with small lumina and simple perforations, tracheids and wood fibres with simple pits. Secondary medullary rays always absent, but primary rays represented by infrequent interruptions of the xylem ring. Xylem more frequently interrupted in species with congested leaves.

Pith often composed of thin-walled parenchyma, e.g. according to Pilger (1725) in *P. indica* and *P. cynops*, but becoming lignified in shrubby species such as *P. arborescens* Poir. and *P. sinaica* Barn. Pith of the rhizome including groups of stone cells in *P. lanceolata* and related species. Rhizomes of *P. atrata* Hoppe subsp. *fuscescens* (Jordan) Pilger, *P. alpina* Linn., and other species sometimes become split up by the formation of **medullary cork,**

which is eventually connected with the outer periderm via the primary medullary rays. **Crystals** very rare in *Plantago*, but observed by Brattsten (263) in *P. fernandezia.*

FLOWERING SCAPE

Flowering scapes of *Plantago* characterized by an **endodermis** situated externally to a more or less definite ring (2 rings in *P. fernandezia* Bert. according to Brattsten (263)) of unlignified fibres in the **pericycle** surrounding a ring of **vascular bundles.** Numerous strands of sieve tubes present between the vascular bundles both in the pericyclic region as well as around the pith. Brattsten (263) observed a more or less continuous ring of phloem, with additional phloem embedded in or situated on the inside of the xylem, in *P. fernandezia.*

WOOD (Fig. 254 E)

Vessels very small, solitary, and in small radial multiples, which are grouped into long radial lines. Perforations simple. Intervascular pitting alternate and small. Members moderately short, mean length about 0·3 mm. **Parenchyma** extremely sparse or absent. **Rays** absent, the spaces between the lines of vessels occupied by fibres whose radial diameters slightly exceed the tangential. **Fibres** with numerous, small pits on both radial and tangential walls, the pits simple or with small borders; extremely short; mean length about 0·4 mm.; walls thin. Solereder states that tracheids are present and numerous cells suggesting **vascular tracheids** were observed.

The above description is based mainly on a single specimen of *Plantago fernandezia* Bert.

ROOT

Mycorrhizal fungi recorded in the cortex of the thin roots of *P. coronopus* Linn. and *P. maritima* Linn. A **cortex** of large, thin-walled cells, a well-marked **endodermis** with slightly suberized walls, and a small **vascular cylinder** with a central mass of xylem recorded in *P. triandra* Berggren by Betts (190).

(ii) LITTORELLA UNIFLORA (L.) ASCHERS (Syn. *L. lacustris* Linn.)

STEM AND RHIZOME

Cork arising in the sub-epidermis. Primary **cortex** containing large intercellular spaces. **Endodermis** composed of large cells with thickened, pitted walls. **Vascular system** consisting of a ring of separate bundles.

ECOLOGICAL ANATOMY

Plantago appears to be a very plastic genus. The very considerable variability of *P. coronopus* Linn. in relation to environment has been described by Gravis (805). Rozenkranz (1950) has shown that the mesophyll structure of *P. lanceolata* Linn. varies according to the orientation of the leaves. Sloping palisade cells present towards both surfaces in isobilateral leaves of this species. Structural variations in response to environment, in species of *Plantago* belonging to the section *Biconvexae*, have been described by Negodi (1584).

P. cretica Linn., a dwarf, stemless annual, is remarkable because, after flowering in the spring, the flowers and their bracts become closely adpressed

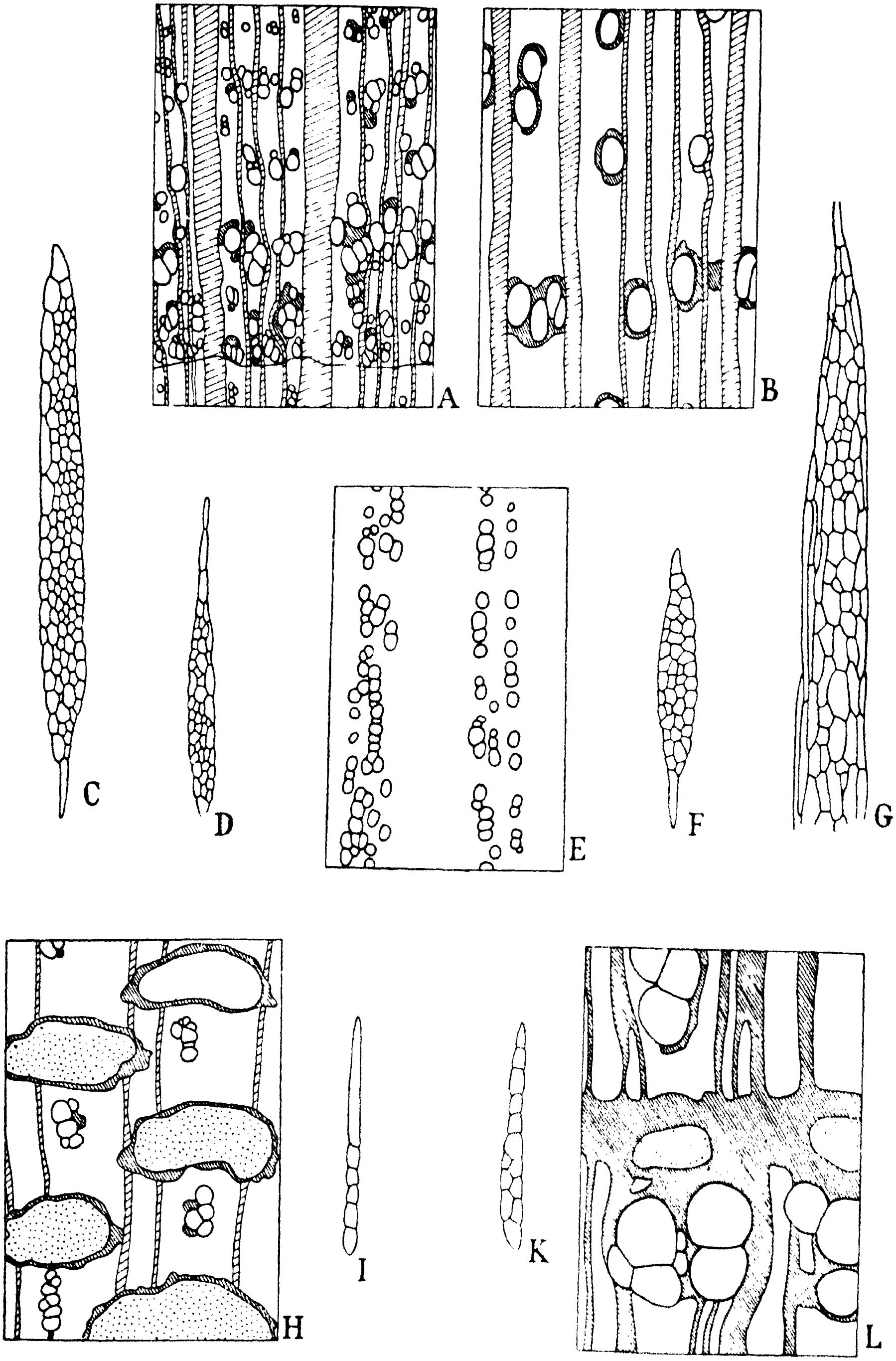


FIG. 254. *LABIATAE*, A–D and F–G; *PLANTAGINACEAE*, E; *NYCTAGINACEAE*, H–L

A, *Lavandula vera* DC. B, *Leucosceptrum canum* Sm. C, *L. canum* Sm. D, *Rosmarinus officinalis* Linn. E, *Plantago fernandezia* Bert. F, *Phlomis fruticosa* Linn. G, *Salvia apiana* Jepson. H, *Pisonia ligustrifolia* Heimerl. I, *Neea amplifolia* Donn. Smith. J, *Torrubia myrtifolia* Standley. K, *Neea psychotrioides* J. D. Sm. L, *Bougainvillaea spectabilis* Willd.

to the inflorescence axis early in the rainless season. At the same time the thick, long, hairy scapes curve outwards like watch-springs, so that the whole plant resembles a spherical body, densely beset with white hairs. With the first winter rain the scapes become erect, the pedicels and bracts spread laterally. The seeds, freely exposed to the wind and the rain, are washed out from the capsules. It was found by Zohary and Fahn (2511) that the pedicels and bracts move as a result of hygroscopic changes, whilst the movement of the scape is determined by a shrinkage mechanism of the prosenchymatous elements.

ECONOMIC USES

Ispaghula or Spogel seeds, derived from *P. ovata* Forsk., contain considerable quantities of mucilage and are used in medicine. Although commercial samples of Ispaghula vary in colour, Skyrme (2128) found the seeds of no other species to be present in them. The seeds of *P. psyllium* Linn. are also used in medicine. Skyrme has recorded the occurrence of samples of '*Psyllium*' consisting partly or wholly of the seeds of *P. indica* Linn. (syn. *P. arenaria* Waldst. et Kit.) and/or *P. lanceolata* Linn. The colour of genuine *P. psyllium* varies to a certain extent. The pharmacognosy and microscopy of 'Folia Plantaginis' has been described by Unger (2313).

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Littorella, Plantago.*

(ii) FOR WOOD STRUCTURE

Plantago.

As far as possible, the nomenclature of the species has been brought into line with that adopted in Pilger's (1725) monograph.

LITERATURE

On General Anatomy

Benoist **171**, Betts **190**, Brattsten **263**, Fischer **686**, Fuchs **731**, Gravis **805**, Negodi **1584**, Oehm **1632**, Pilger **1725**, Rosenkranz **1950**, Skyrme **2128**, Trapp **2275**, Unger **2313**, Zohary and Fahn **2511**.

211. NYCTAGINACEAE

(FIG. 254 on p. 1058; FIG. 255 on p. 1060; FIG. 256 on p. 1062; FIG. 257 on p. 1064)

SUMMARY

(i) GENERAL

Herbaceous and woody plants which occur chiefly in tropical and, to a smaller extent, in temperate parts of America. They are noteworthy from the anatomical point of view on account of the **anomalous growth** in thickness of the axis, by the development of successive rings of collateral vascular bundles. In herbaceous species, the bundles are embedded in parenchymatous ground-tissue, but, in the more woody species, the ground-tissue is somewhat prosenchymatous and lignified. Both types of interfascicular tissue are formed from successive cambial zones. In the more woody species, the boundary between the xylem and adjacent lignified interfascicular tissue is not clearly defined, so that, in transverse sections of a mature stem, the phloem sometimes appears to be in the form of islands. Strips of tissue resembling medullary rays are also laid down in the conjunctive tissue in some instances. The **xylem** of the bundles is made up of vessels, usually with simple perforations but occasionally with reticulate perforation plates, fibres, and parenchyma. The anatomy of the leaf is uninteresting in comparison with that of the stem. The **mesophyll** is dorsiventral in some species, but isobilateral structure is also known to occur. The **hairs,** which may be glandular or non-glandular, do not include any very distinctive forms. The cells of the **epidermis** of both leaf and axis frequently contain varying quantities of

---

* Represented in the Kew slide collection.

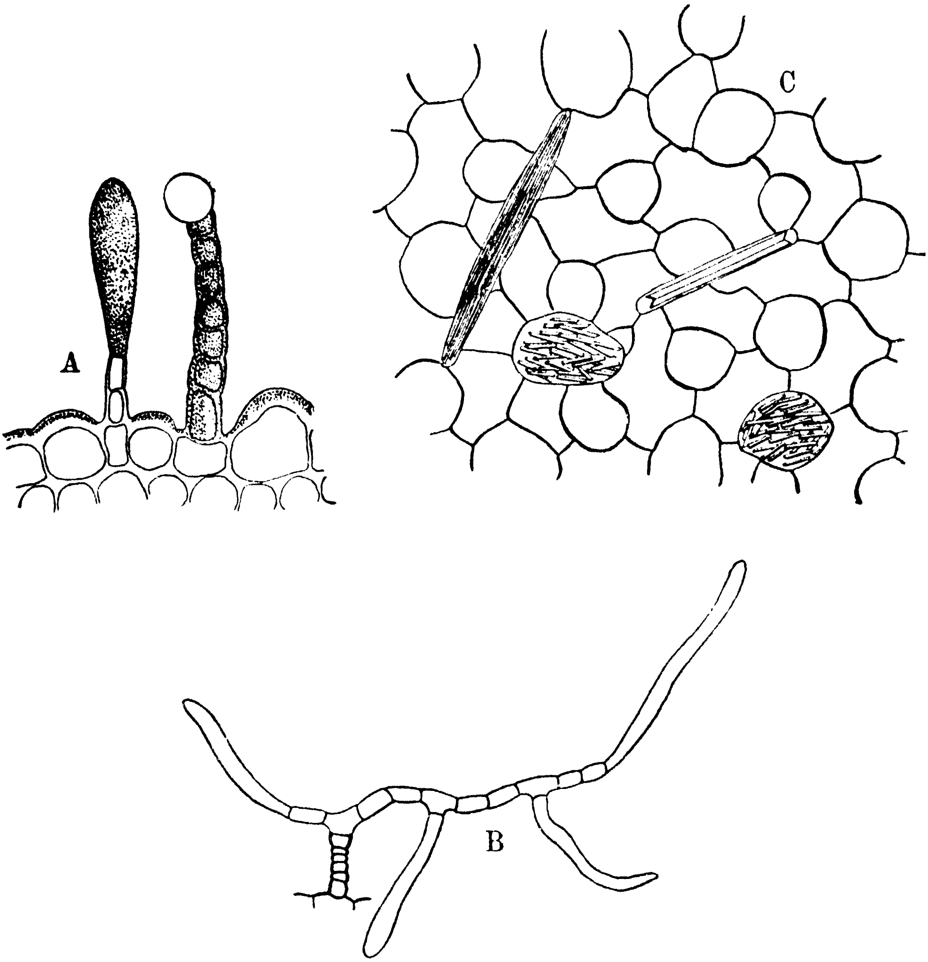


FIG. 255. *NYCTAGINACEAE*

A, Transverse section through the epidermis of *Boerhaavia repens* L. B, Branched trichome of *Pisonia tomentosa* Casar. C, Crystalline elements in the spongy tissue of *P. nitida* Mart.—By Solereder.

crystalline granules. These are not to be confused with ordinary calcium oxalate **crystals,** which occur in other parts of the plant, chiefly in the form of raphides and styloids. Raphides are said by Heimerl (933) to be absent from the Leucastereae. The **stomata** are rather variable in their distribution and in the nature of the surrounding cells; sometimes rubiaceous.

(ii) WOOD

Vessels small, typically in radial groups and clusters behind the phloem strands, perforations nearly always simple, intervascular pitting alternate, often small, pits to parenchyma similar or elongated, members very to extremely short. **Parenchyma** usually very sparse (apart from conjunctive tissue) and limited to a few cells round the vessels, occasionally diffuse or terminal, sometimes storied; raphides characteristic. **Rays** either small and low, 1–2 cells wide, and heterogeneous to homogeneous, or absent, being replaced by radial sheets of conjunctive tissue. **Fibres** with simple pits, sometimes storied, moderately to extremely short. **Included phloem** always present, of either the foraminate or the concentric type.

LEAF

Isobilateral structure recorded in a few species of *Bougainvillaea*, *Phaeoptilum*, and *Selinocarpus*, and approximately isobilateral structure in species of *Acleisanthes*, *Hermidium*, *Mirabilis*. Dorsiventral structure known to occur in species of *Boerhaavia*, *Bougainvillaea*, *Leucaster*, *Mirabilis*, and *Pisonia*. Simple, uniseriate **hairs,** with blunt terminal cells not much larger than the others, widely distributed in *Boerhaavia* (Fig. 255 A), *Bougainvillaea*. Similar hairs but with enlarged terminal cells recorded in *Boerhaavia* (Fig. 255 A). Stellate hairs recorded in *Leucaster*. Branched hairs recorded in *Pisonia* (Fig. 255 B). **Stomata** confined to the lower surface in most of the species examined, but sometimes present on both sides in *Boerhaavia* (Mullan 1571, Sabnis 1977), *Bougainvillaea*, *Phaeoptilum*; ranunculaceous in *Boerhaavia*, *Bougainvillaea*, and *Mirabilis*, but rubiaceous types recorded in other genera. **Hypoderm** reported only in *Phaeoptilum*. Cells of the **mesophyll** sometimes connected to one another by short processes in a few species of *Boerhaavia*, *Bougainvillaea*, and *Mirabilis*. Palisade cells in the dorsiventral mesophyll of *Boerhaavia diffusa* Linn. described by Mullan (1571) as becoming dilated after the monsoon and serving for the storage of water. Water-storage said by Sabnis (1977) to occur in colourless, polygonal cells towards the lower side in the same species, as well as in *B. elegans* Chois. and *B. verticillata* Poir. Vascular bundles of the smaller **veins** surrounded by a sheath of large parenchymatous cells in *B. viscosa* Lag. except opposite the phloem, but the corresponding sheaths of the larger veins in this species are less complete. Somewhat similar sheaths also recorded in *B. diffusa* (component cells described by Mullan (1571) as thick-walled, funnel-shaped, with large chloroplasts at their basal ends) as well as in other species of *Boerhaavia* (excluding *B. verticillata*) and in *Bougainvillaea* and *Phaeoptilum*.

Petiole (Fig. 256 A–C). Vascular system exhibiting the following structure in transverse sections through the distal end of material examined at Kew. (i) A rather deep, sinuous arc of bundles, connected by interfascicular fibres, and enclosing a single, collateral, medullary bundle in *Bougainvillaea glabra*

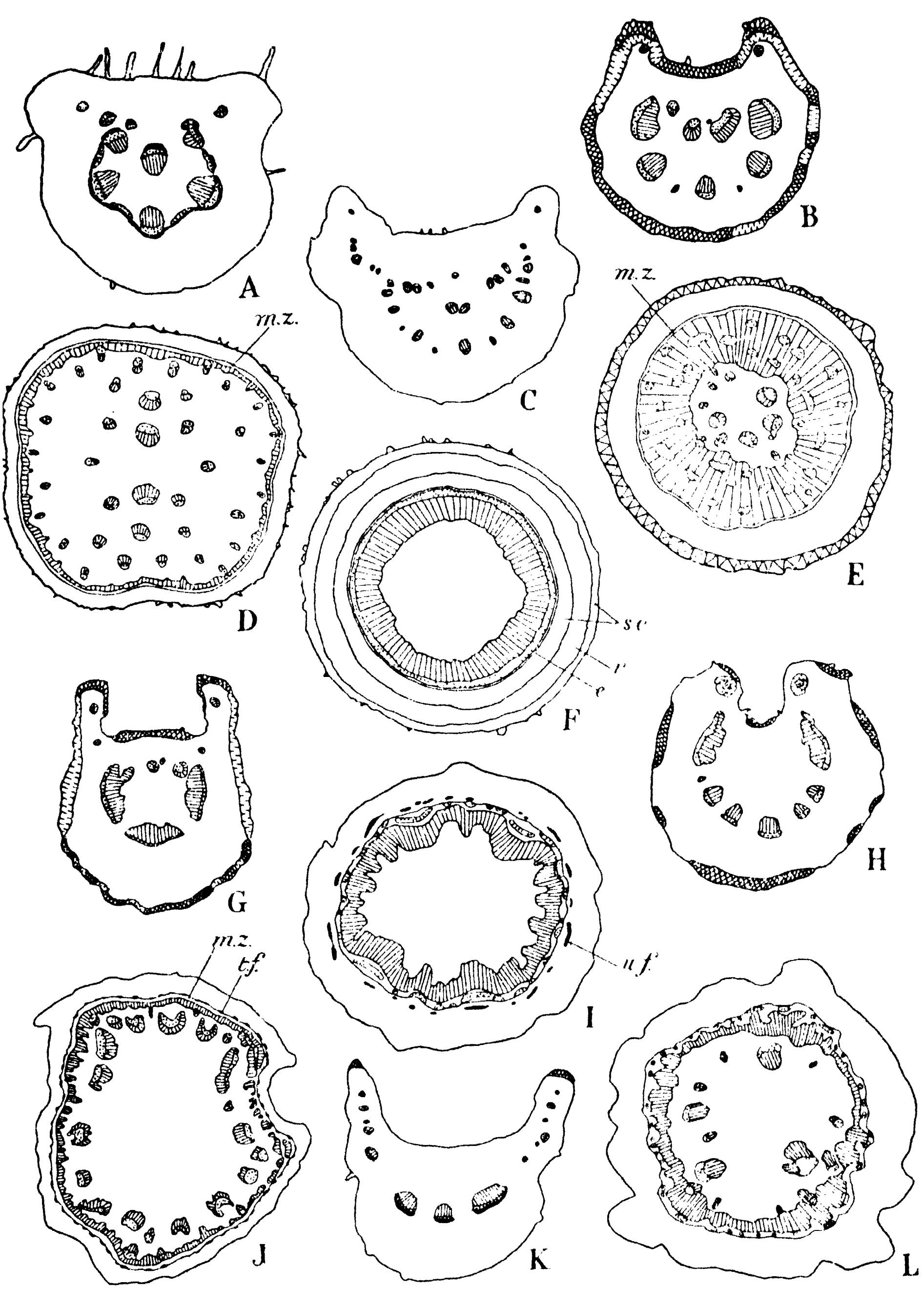


FIG. 256. *NYCTAGINACEAE*, A–E; *PLANTAGINACEAE*, F; *AMARANTHACEAE*, G–L

A, *Bougainvillaea glabra* Chois. Petiole × 27. B, *Mirabilis nyctaginea* (Mich.) Macmill. Petiole × 14. C, *M. wrightiana* A. Gray. Petiole × 9. D, *M. longiflora* Linn. Stem × 6. E, *Neea psychotrioides* J. D. Sm. Stem × 18. F, *Plantago cynops* Linn. Young stem × 21. G, *Celosia cristata* Linn. Petiole × 9. H, *Amaranthus hypochrondriacus* Linn. Petiole × 16. I, *Froelichia gracilis* Moq. Stem × 10. J. *Celosia cristata* Linn. Young stem × 6. K, *Froelichia gracilis* Moq. Petiole × 15. L, *Amaranthus blitum* Linn. Stem × 14.

Numerous crystals in most of the above sections are not shown. *e.* Endodermis. ***r.*** Rectangular cells with thickened walls. ***m.z.*** Meristematic zone with phloem strands. *s.c.* Zones of small cells. ***t.f.*** Thin-walled fibres. *u.f.* Unlignified fibres.

Chois. (Fig. 256 A). (ii) An adaxially concave cylinder of separate bundles surrounding about 3 medullary bundles in *Mirabilis jalapa* Linn. and *M. wrightiana* A. Gray (Fig. 256 C). (iii) Similar to (ii) but with one medullary bundle in *M. longiflora* Linn. (iv) An adaxially flattened circle of bundles and no medullary strands in *Neea psychotrioides* J. D. Smith and *Mirabilis nyctaginea* (Mich.) Macmill. (Fig. 256 B). **Crystals,** besides the crystalline granules mentioned on page 1060, are also secreted in the form of raphides in species of *Boerhaavia* (Sabnis 1977), *Bougainvillaea, Cryptocarpus, Mirabilis*; as mixed styloids and raphides (Fig. 255 C) in species of *Neea, Phaeoptilum, Pisonia*, or as styloids alone in *Neea*. Raphides absent from the Leucastereae according to Heimerl (933); sacs of crystal-sand recorded by Solereder in *Leucaster caniflorus* Chois. Small cluster crystals noted by Mullan (1571) in the upper ends of the palisade cells of *Boerhaavia diffusa* Linn.

AXIS

STEM (Figs. 256 D–E and 257)

Chiefly remarkable for the occurrence of **anomalous secondary thickening** in the form of a succession of rings of vascular bundles in all woody and many herbaceous species, notably in *Boerhaavia, Bougainvillaea, Cryptocarpus, Leucaster, Mirabilis, Neea, Phaeoptilum, Pisonia.* Secondary vascular bundles were at one time believed to originate in the parenchymatous portion of the pericycle, but Maheswari's (1416) work (see p. 1065) has shown that this interpretation is not correct for species of *Boerhaavia* and *Mirabilis* which he investigated. The secondary bundles throughout the family exhibit a concentric or irregular arrangement; becoming embedded in parenchymatous conjunctive tissue in herbs, but in somewhat prosenchymatous, lignified ground-tissue in the more woody species. Inner bundles embedded in parenchyma and outer strands in prosenchymatous ground-tissue in the more robust herbaceous and slightly woody species, e.g. in *Bougainvillaea glabra* Chois. Narrow radial strips, somewhat recalling the medullary rays of stems with more normal structure, sometimes traverse the secondary conjunctive tissue. Thin-walled, lignified groups of parenchymatous cells frequently associated with the phloem; the phloem groups and adjoining ground parenchyma occasionally appear as concentric annular or band-shaped strips of tissue, e.g. in species of *Boerhaavia.* Boundaries between the periphery of the xylem and the surrounding ground-tissue not clearly defined in species having the bundles embedded in prosenchyma, the phloem thus appearing as islands in a xylem mass, e.g. in species of *Neea* and *Pisonia* (Figs. 256 E and 257). Phloem tissue said by Heimerl (933) to become decomposed, thus forming cavities in the ground-tissue. This probably applies especially to herbarium material. The innermost part of the conjunctive tissue, formed by the secondary meristem at the beginning of its activity, often resembles true pith and thus causes the innermost secondary bundles as well as the leaf-traces to appear as if medullary in origin, e.g. in *Bougainvillaea, Mirabilis* (Fig. 256 D), *Neea, Pisonia* (Fig. 257).

Successive zones of closely placed bundles are laid down in definite concentric circles in some specimens of *Calpidia*, the secondary tissues then appearing, in transverse sections, as concentric rings of thin-walled phloem

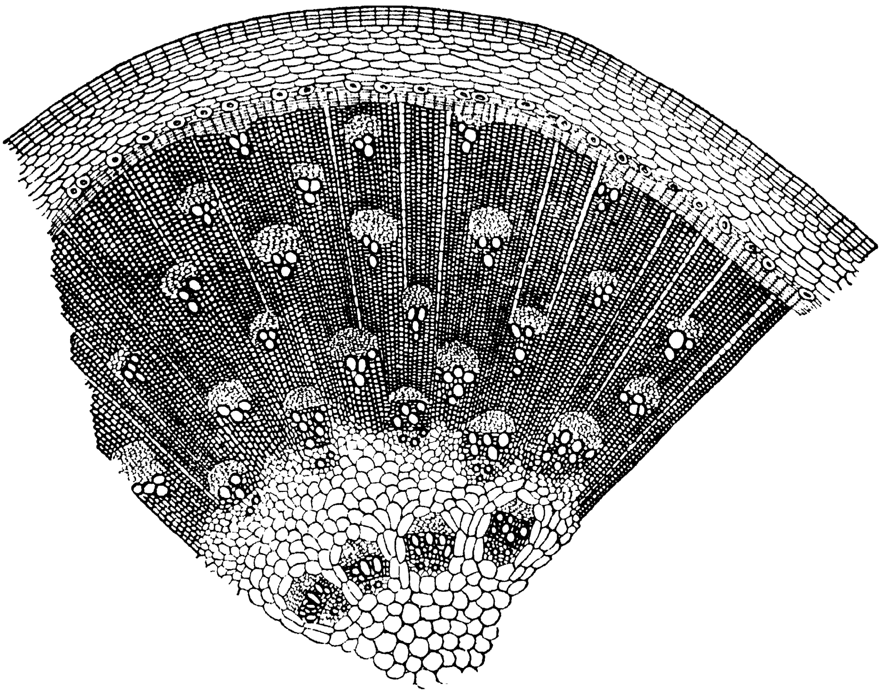


Fig. 257. *NYCTAGINACEAE*
Transverse section through the stem of *Pisonia nigricans* Sw.—By Solereder.

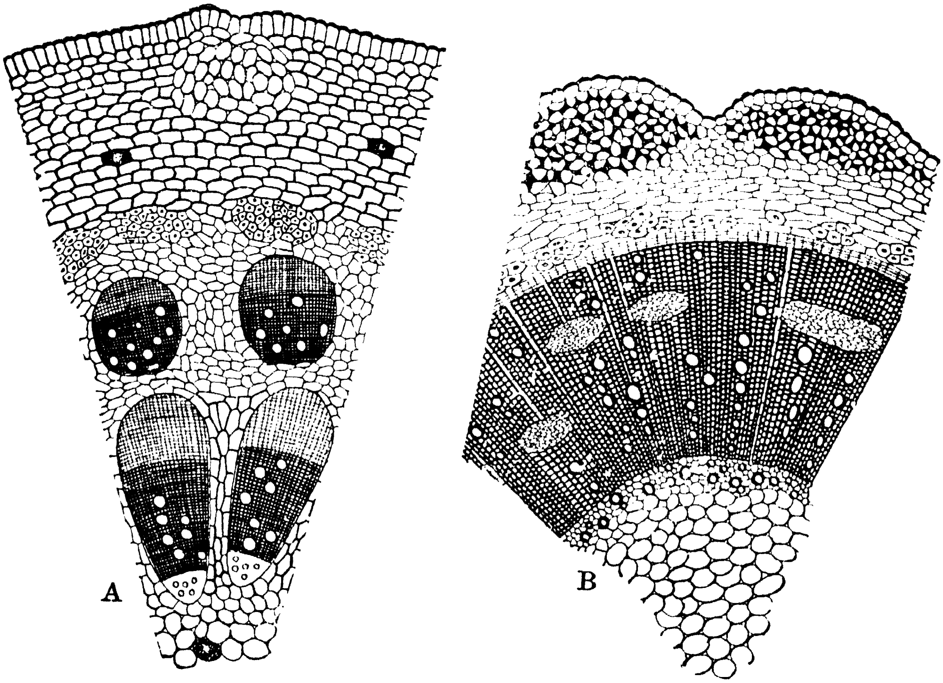


Fig. 258. *AMARANTHACEAE*
Transverse sections through the axis of: A, *Bosea yervamora* L.; B, *Aerva scandens* Wall.—By Solereder.

alternating with rings of denser xylem. The mode of development of the vascular system in the herbaceous *Boerhaavia diffusa* Linn. has been described by Maheswari (1416). Transverse sections through the young stem of this species show 2 medullary bundles, a middle ring of 6–14 bundles and an outer ring of 15–20 or more small bundles. The bundles of the middle ring increase in thickness only to a limited extent by cambial activity which is wholly fascicular. The bundles of the outer cylinder are initially separate, very minute, and each provided with its own fascicular cambium. The fascicular cambial regions of the bundles subsequently become interconnected by interfascicular cambium, thus producing a cylindrical meristem which gives rise internally to xylem and phloem in regions where new bundles are formed and to interfascicular parenchymatous ground-tissue between the bundles. After a time the cambium ceases to be active, and a new meristem arises in the secondary parenchymatous tissue to which the first has given rise on the outside. This process is repeated at intervals. Further particulars concerning anomalous structure recorded under 'Wood' on p. 1066.

Outer part of the primary **cortex** collenchymatous, and inner part consisting of chlorenchyma in *Boerhaavia diffusa* Linn., *B. elegans* Chois., and *B. verticillata* Poir. according to Sabnis (1977). **Endodermis** clearly defined and composed of thick-walled, tabular cells in *B. diffusa* and *B. elegans*. **Cork** arising in the sub-epidermis in species of *Boerhaavia*, *Bougainvillaea*, *Mirabilis*, *Neea*, *Pisonia*; said by Solereder to be more deeply seated in the cortex in some species of *Neea*. Small, isolated strands of sclerenchymatous fibres present in the outer part of the pericycle in species of *Boerhaavia* (Sabnis 1977) (forming a close ring in *B. verticillata*), *Bougainvillaea*, *Cryptocarpus*, *Leucaster*, *Neea*, *Pisonia*; but similar elements known to be absent from at least some species of *Mirabilis*. Primary xylem including vessels with well-developed spiral thickening in species of *Mirabilis* examined at Kew. Vessels mostly with simple perforations; reticulate plates occasional. **Crystals,** of the same kinds as those described under 'Leaf' (p. 1063), usually abundant in the unlignified ground-tissue. Styloids seen to be particularly abundant in species of *Neea*. Crystalline granules in the epidermis, similar to those described under 'Leaf', also occur in the stem. **Secretory cells** with yellow or reddish-brown, tanniniferous contents, sometimes present in the epidermis, and, in the Pinonieae, in the cortex and pith as well, according to Heimerl (933).

WOOD (Figs. 254 H–L and 257)

Vessels usually small (mean tangential diameter less than 100 μ), but often nearly medium-sized and occasionally less than 50 μ; typically in groups of radial multiples and irregular clusters on the inner sides of the phloem strands (Fig. 254 H). Perforations exclusively simple, except for rare, horizontal, reticulate plates in *Boerhaavia* and *Bougainvillaea* (2254). Intervascular pitting alternate, sometimes with striations due to coalescent apertures, small except in *Bougainvillaea*, *Calpidia*, and *Colignonia*; pits to ray and wood parenchyma usually similar, but with some elongated pits in some species of *Calpidia* and *Colignonia*. Mean member length 0·1–0·16 mm. **Parenchyma** usually very sparse, apart from conjunctive tissue; typically as a few cells associated with the vessel groups; with fusiform cells scattered among the fibres in some species of *Torrubia*, and occasionally in terminal bands. Strands up to 2 or 4 cells, but fusiform cells often common; sometimes storied when sufficiently abundant. Conjunctive parenchyma round the phloem often storied and composed mainly of fusiform cells; typically with some cells containing large bundles of raphides;[1] with large single crystals in some species of *Torrubia*. **Rays** in *Neea*, *Pisonia*, *Rockia*, and *Torrubia* small and low, up to 2 or occasionally 3 cells wide or exclusively uniseriate; uniseriates moderately numerous in woods with multiseriate rays, varying from all procumbent cells in woods with homogeneous rays to a mixture of procumbent and upright cells. 5–12 rays per mm.; mostly heterogeneous (Kribs's Types II B and III), but homogeneous in some species of *Torrubia* and almost homogeneous in *Neea*; sometimes, e.g. in *N. amplifolia* Smith, with occasional single marginal rows of very high upright cells (Fig. 254 I); sometimes slightly storied. In *Bougainvillaea spectabilis* Willd. each layer of conjunctive tissue and phloem strands is connected with the next by numerous ray-like radial sheets of conjunctive parenchyma, consisting almost entirely of storied fusiform cells (Fig. 254 L); rather similar radial sheets of parenchyma occur in *Colignonia scandens* Benth., but the cells resemble square or upright ray cells; in *Calpidia nishimurae* (Koidz.) Rehd. et Wils. there are neither rays nor ray-like radial sheets of parenchyma. **Fibres** with small, simple pits, usually equally numerous on both radial and tangential walls; in *Neea*, *Pisonia*, and *Torrubia* the fibres are often storied, particularly in *Pisonia*, and thick-walled. Mean length in *Pisonia* 0·4–0·9 mm. **Included (interxylary) phloem** of the foraminate type (*c.l. foraminulatum*) present in *Neea*, *Pisonia*, *Rockia*, and *Torrubia*, with isolated strands of included phloem that are wider tangentially than radially (Figs. 254 H and 257). Anomalous structure of the concentric type (*c.l. circumvallatum*) present in *Bougainvillaea*, *Calpidia*, *Colignonia*, and *Reichenbachia* (1886), with successive layers of xylem and phloem (Fig. 254 L); the phloem bundles circular in cross-section, e.g. in *Bougainvillaea*, to tangentially elongated, and linked by conjunctive parenchyma; the xylem divided by interfascicular rays in *Bougainvillaea* and *Colignonia*. See also **anomalous secondary thickening** on p. 1063.

ANOMALOUS STRUCTURE, see under 'STEM' and in the preceding paragraph.

ROOT

Often somewhat tuberous. The **anomalous structure** described above for the stem extends to the root in species of *Boerhaavia* (Mullan 1571), *Bougainvillaea*, *Mirabilis*, *Pisonia*. Raphides recorded by Mullan (1571) in the cortex of *Boerhaavia diffusa* Linn.

TAXONOMIC NOTES

In the opinion of Heimerl (933) the Nyctaginaceae are closely related to the Phytolaccaceae. The similarity of the anatomy of these two families lends full support to this view. In discussing the vascular structure of the stem of *Boerhaavia* and *Mirabilis*, Maheshwari (1416) has made a strong plea for regarding the angiosperms as having had a polyphyletic origin, and has suggested that the Centrospermae 'represent a separate and distinct evolutionary line'.

---

[1] Hess (959) found raphides in all of the 37 species of 7 genera of this family that he examined, viz. *Bougainvillaea*, *Calpidia*, *Colignonia*, *Neea*, *Pisonia*, *Rockia*, and *Torrubia*.

ECONOMIC USES

Species of *Bougainvillaea*, &c., are commonly cultivated for ornamental purposes, but the family is otherwise of little economic interest. The tuberous root of *Mirabilis jalapa* Linn. has been used in the same way as Jalap (*Ipomoea* spp., Family Convolvulaceae), see p. 964.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Acleisanthes, Boerhaavia, Bougainvillaea,* Calpidia, Cryptocarpus, Hermidium, Leucaster, Mirabilis,* Neea,* Phaeoptilum, Pisonia, Selinocarpus.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

(Boerhaavia), Bougainvillaea, Calpidia, Colignonia, Neea, Pisonia, (Reichenbachia), Rockia, Torrubia.

LITERATURE

(i) *On General Anatomy*

Dastur and Saxton **543**, Heimerl **933**, Maheswari **1416**, Mirskaja **1540**, Mullan **1571**, Sabnis **1977**, Thompson **2254**.

(ii) *On Wood Structure*

den Berger **182**, Brown, F. B. H. **282**, Burgerstein **312**, Chalk **352**, Chalk and Chattaway **362**, Hess **959**, Janssonius **1154**, Kanehira **1209**, **1214**, Pfeiffer, H. **1712**, Record **1783**, **1809**, **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**, Thompson **2254**, Williams **2430**.

212. AMARANTHACEAE

(FIG. 256 on p. 1062; FIG. 258 on p. 1064; FIG. 259 on p. 1068; FIG. 260 on p. 1072)

SUMMARY

(i) GENERAL

This widely distributed family consists mostly of annual and perennial herbs, but includes some shrubs and a few climbers. The outstanding anatomical peculiarity is the **anomalous growth** in thickness in the axis, which takes place by the development of a succession of collateral vascular bundles from rings or arcs of secondary meristematic tissue in the pericycle. The bundles are embedded in parenchymatous or prosenchymatous ground-tissue. When the ground-tissue is prosenchymatous, the individual bundles are not easy to recognize, because the interfascicular conjunctive tissue and the ground-tissue of the true xylem are so much alike. One of the most characteristic features in the leaf is the sheath of large, cubical, parenchymatous cells by which the vascular bundles of the **veins** are surrounded. No single type of **hair** is particularly widespread in the family, apart from uniseriate trichomes which frequently form a dense, woolly, or silky covering to the leaves. **Crystals** are mostly secreted in the form of sand and/or clusters; solitary types are rare.

(ii) Wood

Vessels small to medium-sized, perforations simple, intervascular pitting alternate and moderately large, pits to parenchyma large and simple; members moderately to extremely short. **Parenchyma** paratracheal, scanty to vasicentric, more rarely aliform, sometimes storied. **Rays** typically absent, being replaced by radial sheets of conjunctive parenchyma; when present, high and broad. **Fibres** with simple pits; sometimes storied; moderately to very short. **Included phloem** of the 'concentric' type characteristic, but occasionally 'foraminate' or intermediate between the two.

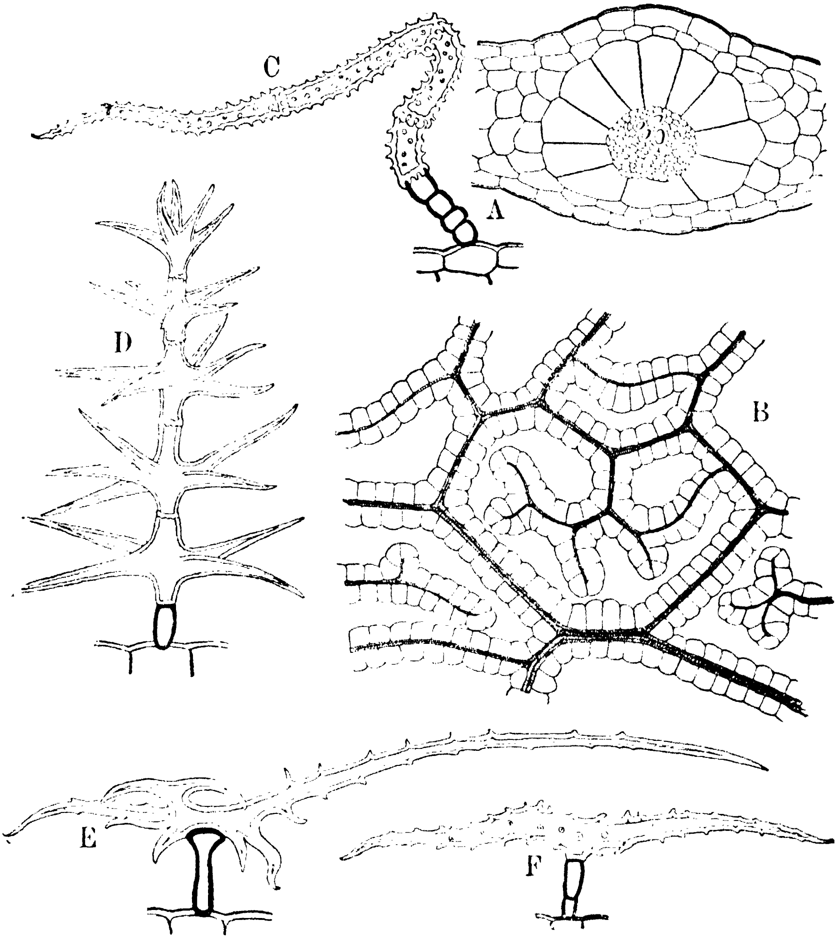


Fig. 259. *AMARANTHACEAE*

A–B, Sheath round the vascular bundles in the veins of the leaf of *Amaranthus blitum* L.: A, in transverse section; B, in surface-view. C–F, Hairs of: C, *Aerva lanata* (L.) Juss.; D, *Cladothrix lanuginosa* Nutt.; E, *Iresine* sp.; F, *Dicraurus leptocladus* Hook. f.—By Solereder.

Only dorsiventral structure recorded, but tending to be isobilateral in *Celosia argentea* Linn. according to Mullan (1571). **Hairs** (Fig. 259 C–F) including a number of special types, each believed to be of somewhat restricted occurrence, but a woolly or silky covering of uniseriate hairs is more widely distributed. Capitate hairs with unicellular, spherical, or ellipsoidal heads recorded in species of *Achyranthes*, *Acnida*, *Allmania*, *Alternanthera*, *Amaranthus*, *Gomphrena*, *Iresine*. Special hairs recorded by Solereder include the following types: (i) Two- or many-armed, multicellular trichomes, with yellow walls to the short basal cells of the stalks, in *Ptilotus latifolius* R. Br. (ii) Papillose 2-armed trichomes with unicellular, sometimes slightly branched head cells, supported by short stalks in *Dicraurus* (Fig. 259 F) and *Iresine* (Fig. 259 E). (iii) Papillose, uniseriate trichomes of *Aerva lanata* (L.) Juss. (Fig. 259 C) composed of interlocking cells, the short basal ones being provided with yellow walls. (iv) Candelabra hairs (Fig. 259 D) in *Aerva* (Sabnis 1977), *Alternanthera*, *Telanthera*, *Tidestromia*. (v) Stellate hairs recorded in a few species, e.g. in *Tidestromia*. **Stomata** present on both surfaces of the leaf, but usually more numerous on the lower than on the upper side, in species of *Achyranthes*, *Aerva*, *Allmania*, *Amaranthus*, *Celosia*, *Gomphrena*, and *Pupalia*. Vascular bundles of both large and small **veins** commonly surrounded by sheaths of usually green, almost cubical, parenchymatous cells (Fig. 259 A–B); sheathed by clear parenchymatous cells in *Celosia argentea* Linn. according to Mullan (1571). **Petiole** (Fig. 256 G, H, K), in transverse sections through the distal end, exhibiting an arc of separate bundles in species of *Amaranthus*, *Froelichia*, and *Gomphrena* examined at Kew. An adaxially flattened cylinder of separate bundles seen in *Celosia cristata* Linn. (Fig. 256 G). Petiolar vascular strands towards the wings, in most of the species examined at Kew, sheathed with very large, parenchymatous cells. Petiolar vascular strands seldom supported by fibres. **Crystals** most characteristically secreted in the form of sand, but clusters of larger crystals also occur, both of these types being found together in the same leaf in some instances; solitary crystals rare. Cluster crystals especially large and numerous in *Iresine* according to Schinz (2033). Crystal-sand recorded in the axis as well as the leaf in species of *Acnida*, *Allmania*, *Amaranthus*, *Bosea*, *Celosia*, *Chamissoa*, *Cyathula*, *Deeringia*, *Pupalia*. Crystalloids said to occur in the chloroplasts in species of *Achyranthes* and *Alternanthera*.

AXIS

STEM (Figs. 256 I, J, L and 258 A–B)

Frequently angular, with collenchyma well developed in the ribs. Collenchyma forming a ring in the outer part of the **cortex**, between the epidermis and assimilatory tissue, in some species, e.g. of *Amaranthus* and *Gomphrena*. Assimilatory tissue usually consisting of 3–7 layers of isodiametric cells. Palisade assimilatory tissue in the cortex recorded in *Aerva* by Sabnis (1977) and in *Celosia* by Mullan (1571). **Cork** occasionally present in old stems, originating in the sub-epidermis, e.g. in species of *Amaranthus*. **Endodermis** frequently conspicuous; consisting of moderately thick-walled, amyliferous cells in *Froelichia gracilis* (Hook. f.) Moq. and *Gomphrena globosa* Linn. **Pericycle** usually including small strands, and, less frequently, a slightly interrupted ring of fibres. Long thin strands of fibres in *Aerva*, and triangular strands in *Pupalia*, recorded by Sabnis (1977); a slightly interrupted ring noted at Kew in *Gomphrena globosa*.

Vascular system nearly always exhibiting **anomalous secondary thickening.** The anomalous structure arises when secondary rings or arcs of meristem in the pericycle give rise to a succession of collateral vascular bundles. The latter are arranged in concentric circles if they originate from closed rings of cambium, but are irregularly distributed when formed from cambial arcs. The conjunctive tissue between the bundles consists of parenchyma (Figs. 256 J, L and 258 A) in some species, or, in others, of lignified or unlignified prosenchyma (Fig. 258 B). Frequently the ground-tissue is wholly lignified in some growth-zones and wholly parenchymatous in others. In other species the individual bundles of a single growth ring are partly or wholly connected by sclerenchymatous interfascicular tissue, whilst concentric zones of parenchymatous tissue separate consecutive growth rings. In fact a considerable range of variation in the nature of the ground-tissue occurs in different species throughout the family. It was noted at Kew that the outlines of the vascular bundles of *Gomphrena globosa* are not clearly defined, because the bundles are embedded in a ring of interfascicular sclerenchyma composed of cells very similar to those of the ground-tissue of the xylem. This doubtless applies in other genera and species as well. Schinz (2033) has described the secondary ground-tissue as resembling pith when it is wholly parenchymatous, the vascular strands then appearing as if they are medullary bundles (Fig. 256 J and L). In other species there are true medullary bundles, and in a third group no bundles are present within the peripheral ring (Fig. 256 I).

Anomalous thickening has been recorded in species of *Achyranthes*, *Acnida*, *Aerva*, *Alternanthera*, *Amaranthus*, *Bosea*, *Celosia*, *Chamissoa*, *Deeringia*, *Froelichia*, *Gomphrena*, *Hermbstaedtia*, *Iresine*, *Pfaffia*, *Psilotrichum*, *Pupalia*. According to Solereder the only species where anomalous structure has not definitely been recorded is *Tidestromia lanuginosa* (Nutt.) Standley (syn. *Cladothrix lanuginosa* Nutt.), but anomalous structure was also not observed by Sayeedud-Din (2007) in *Allmania nodiflora* (L.) R. Br.

According to Joshi (1199) anomalous secondary thickening in this family and in the Chenopodiaceae may be present in the root or base of the stem when it is absent from the rest of the stem. Parenchymatous conjunctive tissue is more abundant in the root than in the stem and decreases upwards. In some genera, e.g. in *Achyranthes*, while the secondary cambiums form large arcs or complete rings in the root, they are limited in the stem to small arcs. Joshi concludes that the formation of a succession of cambiums is an ancestral character in these families, the primitive form having several zones of vascular bundles embedded in a parenchymatous ground-tissue and formed from a similar number of secondary cambial rings. Evolution has led either to the loss of anomalous thickening from the stem alone or from stem and root, or to the reduction of the secondary cambiums to smaller and smaller segments. This, combined with conversion of the conjunctive parenchyma to fibrous conjunctive tissue, has led to the development of included phloem of the 'foraminate' type.

For further notes on anomalous structure see under 'Wood' on p. 1073.

The number and arrangement of the true **medullary bundles** is not constant throughout the length of an individual plant. Thus it has been shown by Joshi (1194, 1196) that in *Achyranthes aspera* Linn. 2 separate medullary bundles occur throughout the length of an internode only in the region immediately below the inflorescence. Elsewhere they exist as separate bundles immediately above or below a node, whilst they unite to form a single amphixylic bundle elsewhere in the internode. Joshi, whose early observations were not quite in accord with those of Dastur (541), eventually discovered that the arrangement of the medullary bundles varies somewhat in specimens of the same species collected from different localities. Thus 2 separate medullary bundles were noted by Dastur in all of the internodes throughout the plant. Material from Bombay, submitted by Dastur to Joshi, showed the medullary bundles to be fused in some 20 per cent. of the internodes examined. On the other hand, fused medullary bundles were seen in only one instance in plants from Calcutta and in about 50 per cent. of the plants from Benares that were examined. In the inflorescence of the same species there are 4 to 8 or 9 medullary bundles which develop earlier than those of the peripheral ring. Joshi has also recorded the occurrence of 4 medullary bundles in *Cyathula prostrata* (L.) Blume and their absence from *Pupalia lappacea* Juss. The absence of medullary bundles from *Arthraerua* has also been recorded by Zemke (2505), and noted at Kew in *Froelichia gracilis* (Hook. f.) Moq. and *Gomphrena globosa* Linn. The medullary bundles of the Amaranthaceae have also been studied by Wilson (2347), who put forward the view that they have arisen by the gradual advance of bundles from the peripheral circle into the pith, this change having been initiated in the node, and extended up and down the stem.

The course of the vascular bundles in the stem has been the subject of numerous extensive and detailed investigations, some of the more important being those by Dastur (541), Gravis (803), Joshi (1194, 1196, 1199), Mao (1436), Schmid (2036), Wilson (2347).

Pith composed of large thin-walled cells recorded by Sayeedud-Din (2007) in *Allmania nodiflora*. **Secretory elements.** Cells with a red pigment dissolved in the sap frequently occur in the epidermis and primary cortex. Clustered **crystals** of calcium oxalate, crystal-sand and/or occasional solitary crystals present in all examined species.

Floating stems of *Alternanthera aquatica* (Parodi) Chod. The following particulars have been recorded by Chodat and Rehfous (404). Hairs simple, uniseriate, containing crystalliferous deposits; transverse septa of trichomes provided with small protuberances. Primary cortex composed of spongy parenchyma with a well-developed system of intercellular spaces. Endodermis differentiated as a starch layer. Vascular bundles consisting mainly of tissues of secondary origin. Pith fistular. Sclerenchyma absent. The erect stems of the same species exhibit fewer lacunae in the cortex, a circle of fibres in the pericycle, a less fistular pith occupied by spongy tissue composed of triangular cells. Interfascicular xylem more fully developed in erect stems of *Alternanthera philoxeroides* (Mart.) Griseb. than in the above species.

WOOD (Figs. 258 A and 260)

Vessels varying from small to medium-sized (range of mean diameters measured 40–140 μ), solitary and in radial groups of 2 or 3; in small radial groups behind the phloem strands in *Nototrichium*; 4–30 per mm. Perforations simple. Intervascular pitting alternate, usually moderately large; pits to parenchyma often larger, elongated and simple. Mean member length 0·1–0·3 mm. **Parenchyma** paratracheal, limited to a few cells round the vessels in *Bosea yervamora* Linn. and *Nototrichium sandwicense* Hbd., and

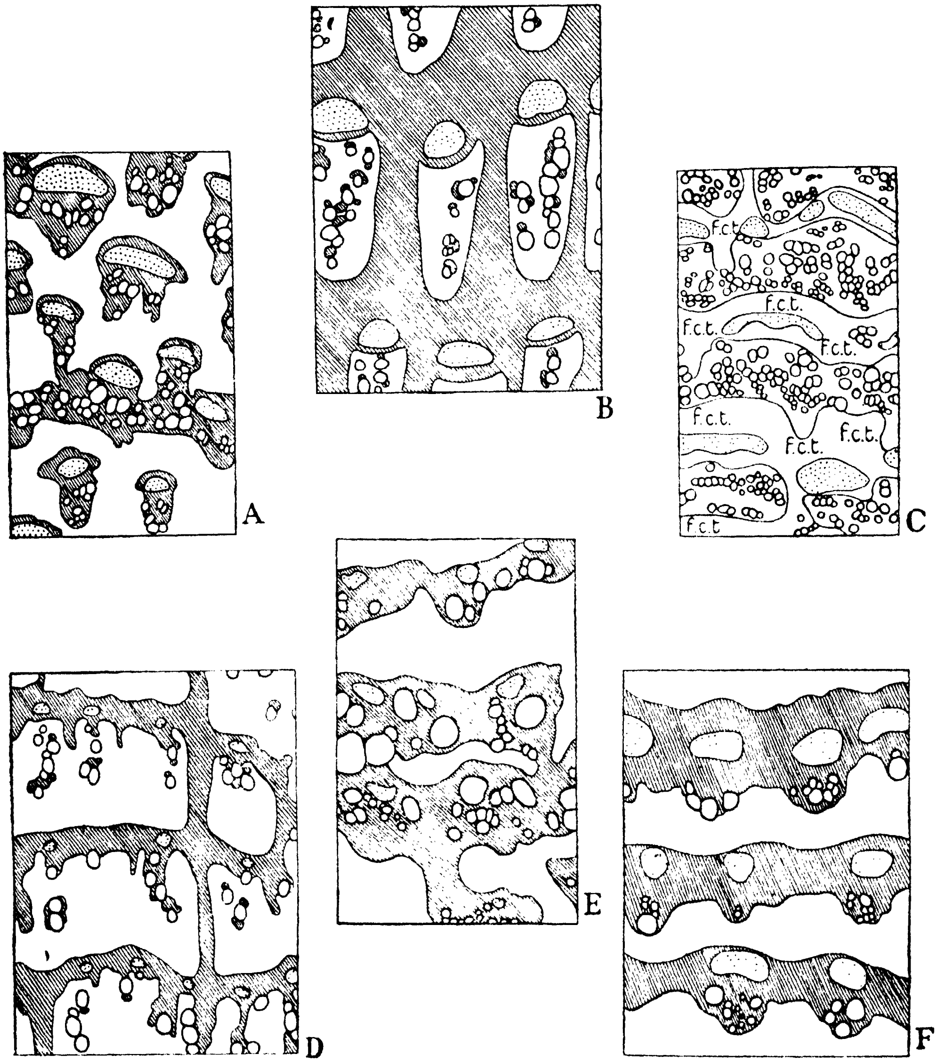


FIG. 260. *AMARANTHACEAE*, B; *CHENOPODIACEAE*, A, C–F
A, *Eurotia lanata* (Pursh.) Moq. B, *Bosea yervamora* Linn. C, *Grayia spinosa* (Hook.) Moq. D, *Suaeda torreyana* Watts. E, *Sarcobatus vermiculatus* (Hook.) Torr. F, *Atriplex canescens* Nutt.
f.c.t. Fibrous conjunctive tissue.

vasicentric in *Chamissoa* and *Iresine* (376); more abundant and sometimes aliform to confluent and not easily distinguishable from the conjunctive parenchyma surrounding the phloem strands in *Charpentiera ovata* Gaudich. Strands of 1–4 cells; fusiform cells usually present and numerous in *Charpentiera*, particularly in the conjunctive parenchyma. The conjunctive tissue containing crystal-sand in *Bosea*. Storied in *Charpentiera* and *Iresine* (376). **Rays** in *Charpentiera* more than 1 mm. high and up to 10 cells wide; uniseriate rays absent, but with occasional small rays 2–3 cells wide and 1 story high; the larger rays with sheath cells, but with the marginal rows not distinctly higher than the inner rows. True rays absent from the other genera examined (*Bosea*, *Nototrichium*, and *Pfaffia*), but with the successive layers of conjunctive tissue linked by ray-like, radial sheets of interfascicular conjunctive parenchyma. **Fibres** with simple pits that may be more numerous on the radial walls, e.g. in *Bosea*, or on the tangential walls, e.g. in *Charpentiera*. Storied in *Charpentiera*. Mean length 0·5–0·8 mm. (100). **Included (interxylary) phloem** of the 'concentric' type (*c. l. circumvallatum*) stated by Pfeiffer (1712) to occur in *Achyranthes* L., *Acnida* Mitch., *Alternanthera* Forsk., *Amaranthus* L., *Bosea* L., *Celosia* L., *Chamissoa* H. B. et K., *Deeringia* R. Br., *Froelichia* Moench., *Gomphrena* L., *Hermbstaedtia* Reichb., *Pfaffia* Mart., *Psilotrichum* Bl., *Pupalia* Adans., *Rodetia* Moq., and *Uretia* Adans. Included phloem also reported (376) in *Iresine*. In *Nototrichium sandwicense* Hbd. the anomaly is of the 'foraminate' type, as in many of the Nyctaginaceae, e.g. in *Neea*; in the only available specimen of *Charpentiera* (*C. ovata*) the anomaly appears to be of the same type, though without the grouping of the vessels; but owing to the condition of the specimen no actual phloem could be found in the torn, disintegrated strands. For further particulars concerning anomalous structure see under 'Stem'.

ANOMALOUS STRUCTURE, *see above, under* 'Stem' *and* 'Wood'

ROOT

Anomalous thickening of the type described under 'Stem' occurs also in the root, the first accessory cambium arising in the pericambial region, and the subsequent ones in the secondary ground-tissue. See also under 'Stem' on p. 1070. **Aquatic roots** of *Alternanthera aquatica* (Parodi) Chod. exhibit, according to Chodat and Rehfous (404), a spongy cortex with radially arranged lacunae; a well-defined endodermis with casparian thickenings; 3 poorly developed xylem groups not extending to the centre of the root; an absence of absorbing hairs.

TAXONOMIC AND PHYLOGENETIC NOTES

The Amaranthaceae are anatomically similar to the Nyctaginaceae, but differ from this last family in containing no raphides or styloids. The types of calcium oxalate crystals which occur in the Amaranthaceae bring this family more into line with the Caryophyllaceae than with the others which belong to the Centrospermae. The Amaranthaceae and Chenopodiaceae are also alike in exhibiting similar anomalous secondary thickening.

After investigating the medullary bundles of *Achyranthes aspera* Linn., Joshi (1196) concluded that the possession of these strands has been a comparatively recent phylogenetic development, and that the fusion of separate medullary bundles took place still later on. After investigating the distribution in India of forms of *Achyranthes aspera* with differently arranged medullary bundles Joshi also concluded that the species originated in tropical regions, whence it spread to cooler parts of the country.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Achyranthes, Acnida, Aerva, Allmania, Alternanthera, Amaranthus,* Arthraerua, Bosea, Celosia,* Chamissoa, Cyathula, Deeringia, Dicraurus, Froelichia,* Gomphrena,* Hermbstaedtia, Iresine, Psilotrichum, Ptilotus, Pupalia, Tidestromia.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Bosea, (Chamissoa), Charpentiera, (Iresine), Nototrichium, (Pfaffia).

LITERATURE

(i) *On General Anatomy*

Chodat and Rehfous **404**, Dastur **541**, Gravis **803**, Joshi **1193**, **1194**, **1196**, **1199**, Kienholz **1236**, Mao **1436**, Mullan **1571**, Sabnis **1977**, Sayeedud-Din **2007**, Schinz **2033**, Schmid **2036**, Wilson **2347**, Zemke **2505**.

(ii) *On Wood Structure*

Bailey and Tupper **100**, Brown, F. B. H. **282**, Burgerstein **312**, Chalk and Chattaway **362**, Joshi **1199**, Kanehira **1209**, Pfeiffer, H. **1712**, Record **1781**, **1809**, **1843**, **1851**.

213. CHENOPODIACEAE

(FIG. 260 on p. 1072; FIG. 261 on p. 1076; FIG. 262 on p. 1078; FIG. 263 on p. 1080)

SUMMARY

(i) GENERAL

This cosmopolitan family consists mainly of herbs, but includes some shrubs, and even small trees. The aerial parts of the plant, notably in *Salicornia*, are very plastic, thereby making specific identification difficult. Many members of the family are particularly characteristic of maritime regions and localities with saline soils. In correlation with this type of habitat, the leaves are often succulent or reduced in size, whilst, in some instances, the stem is succulent and takes on the function of carbon assimilation. Segmented stems occur in *Anabasis*, *Haloxylon*, and *Salicornia*. The tap-root of xerophytic species often extends very deeply into the ground; in other species it becomes fleshy, e.g. in the Beetroot. Turnip-shaped rhizomes occur according to Ulbrich (2311) in species of *Bassia*, *Camphorosma*, *Chenopodium*, *Suaeda*. The **mesophyll** is dorsiventral to centric, or composed of palisade assimilatory tissue and water-storage cells. Various special types of mesophyll also occur, of which some are described on p. 1077. The **hairs** are of many diverse types including uniseriate, 2-armed, branched, stellate, and vesicular kinds. Glandular hairs which secrete oil also occur. The hairs are sufficiently numerous to form a white, woolly indumentum in a few species of *Chenolea*, *Cornulaca*, *Enchylaena*, *Eurotia*, *Halimocnemis*, *Panderia*. **Stomata** are generally present on all parts of the leaf surface, the pores usually being orientated transversely to the median vein. The axis is chiefly remarkable for its **anomalous secondary thickening,** whereby concentric zones of or irregularly distributed collateral vascular bundles arise from a succession of arcs or rings of cambium, the latter being mostly situated in the pericycle or occasionally the phloem. These secondary meristems also give rise to the conjunctive tissue in which the bundles are embedded. The similarity of the ground-tissue of the bundles to the interfascicular conjunctive tissue sometimes obscures the outlines of the bundles in transverse sections. Anomalous secondary thickening occurs in all species with relatively thick stems, but is unknown in the upper part of the stem in some instances, and has not been seen at all in a few genera with thin stems. The root is known to exhibit the same type of anomalous structure as the stem in a number of genera and species. The vessels of the secondary **xylem** in young stems vary from 15 to 45 μ in diameter in most instances, but are wider in climbers such as *Hablitzia*. The perforations are simple. **Cork** is often poorly developed or absent; when present its seat of origin is very variable. When it arises in the pericycle it is closely associated with the cambial regions from which the secondary bundles are formed. Special types of stem structure, some of which are described on p. 1081, occur in succulent plants of the *Salicornia* type. **Crystals,** which are often abundant, are secreted chiefly in the form of clusters or as sand, but other types sometimes occur.

(ii) WOOD

Vessels small, typically in clusters on the inner sides of the phloem strands, sometimes tending to be ring-porous, commonly with spiral thickening, perforations simple, intervascular pitting alternate and small, pits to parenchyma similar, members extremely short. **Parenchyma** (*a*) conjunctive, linking the strands of phloem in broad, irregular bands, (*b*) scattered round and among the vessel groups; typically with numerous fusiform cells and storied. **Rays** absent and radial linkages between the bands of conjunctive parenchyma relatively few. **Fibres** with simple pits, extremely short. **Included phloem** of the 'concentric' type typical.

LEAF

Leaves developed as typical, flattened, assimilatory organs in only a few genera, e.g. in *Atriplex*, *Beta*, *Chenopodium*, *Hablitzia*, *Obione*, and *Rhagodia*; much reduced in size in many other genera, the green stems assuming equal or greater importance for photosynthesis. Leaves frequently exhibiting special types of structure in correlation with the maritime habitat of many members of the family.

Hairs (Fig. 261) including many diverse kinds, some of these being valuable for diagnostic purposes. (A) Uniseriate hairs, widely distributed. (i) Consisting of rather numerous, thin-walled cells, e.g. in species of *Chenopodium*. (ii) Each having a basal portion of 1 to several thin-walled cells, and a long, unicellular or uniseriate terminal part, the latter composed of thick-walled, papillose cells, e.g. in *Camphorosma*, *Chenolea*, *Kirilowia* (Fig. 261 A), *Salsola*, &c. (B) Two-armed hairs, with papillose terminal cells in *Petrosimonia* (Fig. 261 B). (C) Branched or candelabra hairs recorded in species of *Agriophyllum*, *Axyris*, *Ceratocarpus*, *Corispermum* (Fig. 261 K), *Eurotia*, *Grayia*. (D) Stellate hairs. (i) With short stalks and stellately branched terminal cells recorded in *Grayia* (Fig. 261 G) and *Eurotia* (Fig. 261 H). (ii) Long uniseriate hairs with a few basal stellate arms in *Axyris* (Fig. 261 J). Stellate hairs also recorded in *Kochia planifolia* F. v. Müll. by Wood (2457). (E) Vesicular hairs (Fig. 261 C–E) each, when young, consisting of a unicellular or uniseriate stalk bearing a distended head containing water and often oxalates in solution or in the form of crystals. These vesicular hairs dry up when mature, and their remains form a white powder on the surface of the leaf. They have been observed or recorded in many species of *Atriplex*, *Axyris*, *Chenopodium*, *Cycloloma*, *Kochia*, *Monolepis*, *Obione*, *Rhagodia*, *Roubieva*, *Salsola*, *Teloxys*. (F) Uniseriate, oil-secreting, glandular hairs (Fig. 261 L–O) recorded in *Camphorosma*, *Chenopodium*, *Roubieva*.

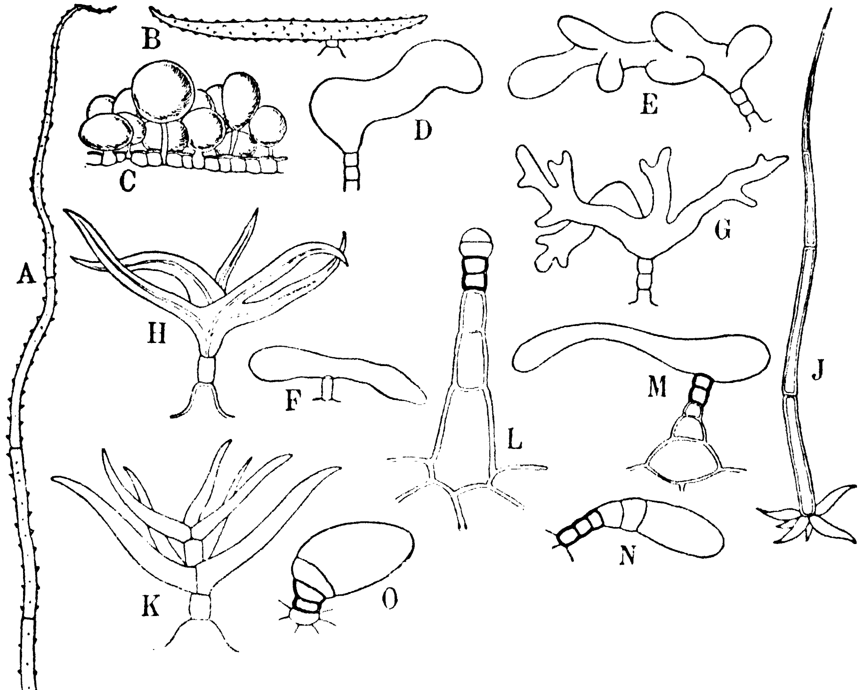


FIG. 261. *CHENOPODIACEAE*

Hairs of: A, *Kirilowia eriantha* Bge.; B, *Petrosimonia sibirica* (Pall.) Bge.; C, *Atriplex leucoclada* Boiss.; D–E, *Grayia polygaloides* Hook. et Arn.; F, *Chenopodium album* L.; G, *Grayia polygaloides* Hook. et Arn.; H, *Eurotia ceratoides* (L.) C. A. Mey.; J, *Axyris amarantoides* L.; K, *Corispermum hyssopifolium* L.; L, *Chenopodium botrys* L.; M–O, *C. ambrosioides* L.—A–K after Volkens, the remainder by Solereder.

Epidermis rarely provided with a thick cuticle, e.g. in species of *Agriophylum*, *Anabasis* (Hauri 921), *Noaea*, but sometimes coated with wax. Small, solitary crystals recorded by Zemke (2505) in the thick-walled epidermal cells of *Salsola zeyheri* (Moq.) Schinz. **Hypoderm** of aqueous cells sometimes differentiated, e.g. beneath each epidermis in *Atriplex vesicarium* Heward according to Wood (2457), and in *Salsola zeyheri* (containing cluster-crystals) according to Zemke (2505). Hypoderm also recorded by Sabnis (1977) in species of *Haloxylon* and *Salsola*. **Stomata** always present on all parts of the surface of the leaf, whether this be cylindrical or flattened; frequently with their pores orientated transversely to the longitudinal axis; generally without special subsidiary cells (ranunculaceous), but rubiaceous types recorded in a few species of *Camphorosma*, *Salicornia* (surface of the stem), *Salsola*, *Suaeda*; depressed below the surface in some, but by no means in all, species. **Hydathodes** recorded by Cumming (512) on the lower surface near the apex of the leaf in a species of *Atriplex*.

Mesophyll dorsiventral, consisting of 1 or more layers of palisade cells towards the adaxial surface and of rather dense spongy tissue below in species of *Anthochlamys*, *Beta*, *Chenopodium*, *Spinacia*, &c.; composed of a homogeneous tissue of rounded cells, e.g. in *Axyris hybrida* Linn.; centric in species of *Beta*, *Kochia*, *Lophiocarpus*, and *Salsola* (Fig. 262 B); sometimes isobilateral, e.g. in *Atriplex* (Fig. 262 C). Mesophyll often exhibiting specialized structure in correlation with the halophytic conditions under which many of the species grow, the specializations consisting of various arrangements of assimilatory and water-storage tissue. The following 3 types were recognized by Ulbrich (2311) whose account is based on an earlier description by Solereder. (i) Several layers of colourless, palisade cells extending from below the upper epidermis almost to the centre of the mesophyll in *Rhagodia baccata* (Labill.) Moq. (ii) Aqueous tissue present beneath the upper and lower epidermis, the assimilatory tissue being confined to the centre of the mesophyll and around the vascular bundles (Fig. 262 C). Assimilatory tissue, in a closely allied type, in the form of a meshwork accompanying the vascular bundles, but with aqueous cells between the circumvasal chlorenchyma of each of the veins (Fig. 262 A). Both of these types recorded in species of *Atriplex*, *Bassia*, *Chenolea*, *Kirilowia*, *Kochia*, *Panderia*. The second variation of type (ii), sometimes described as exhibiting 'Kranz' structure, has been specially investigated by Moser (1563) (see under 'Veins' on p. 1078). (iii) Assimilatory tissue occupying a narrow zone beneath, but sometimes separated from, the epidermis by a hypoderm, the remainder of the organ being occupied by a compact cylinder of aqueous tissue with thin-walled vascular elements embedded in it. This type of structure occurs in all approximately cylindrical assimilatory organs, whether these are morphologically leaves or stems, in such genera as *Camphorosma*, *Corispermum*, *Salicornia*, *Salsola*, and *Suaeda*. A highly specialized type of leaf has been described in *Fredolia* (*Anabasis*) *aretioides* Coss. et Dur. by Hauri (921). The leaf, which is both fleshy and fibrous, is traversed by a central strand of fibres, which serves as the support for a dome consisting of the thick-walled, multicellular epidermis on the upper side of the leaf. Below the upper epidermis there are 3 layers of tissue which are likewise dome-shaped. The outermost layer consists of aqueous tissue, the middle layer of chlorenchyma and the inner layer of parenchyma with a vascular network embedded in it. Hauri's account of the leaf of this species is not quite in accord with that published more recently by Rosengart-Famel (1949), who figures a vascular bundle in the position which, according to Hauri, is occupied by the strand of fibres which supports the dome of thick-walled cells of the upper epidermis. According to Giovannozi and Geremicca, as quoted by Ulbrich (2311), the chloroplasts in the palisade tissue of *Atriplex nummularia* Lindl. and certain other species are much larger and of a more vivid green than those in the aqueous tissue. Mesophyll of *Rhagodia gaudichaudiana*

R. Br. described by Wood (2457) as consisting, apart from large aqueous cells, of slightly palisade-like cells scattered throughout the leaf.

Midrib containing 2 vascular bundles in *Atriplex vesicaria* Heward according to Wood (2457). Vascular bundles of the **veins** frequently surrounded by a sheath of large, thick-walled cells, often containing chlorophyll, the palisade cells of the mesophyll usually being orientated radially around the circumvascular sheaths. This so-called 'Kranz' type of structure (see also under 'Mesophyll' on p. 1077) has been reported by Moser (1563) to occur in species of *Atriplex*, *Bassia*, *Kirilowia*, *Kochia*, *Panderia*, and *Polycnemum*. A detailed examination of about 100 species of *Atriplex* by the same investigator showed 'Kranz' structure to occur in a large majority. A corky layer recorded by Zemke (2505) around the central vascular bundle of *Salsola zeyheri* (Moq.) Schinz, storage tracheids also being present near the central vascular strand in the same species. Central vascular strand sheathed by stone cells in *Salsola foetida* Del.

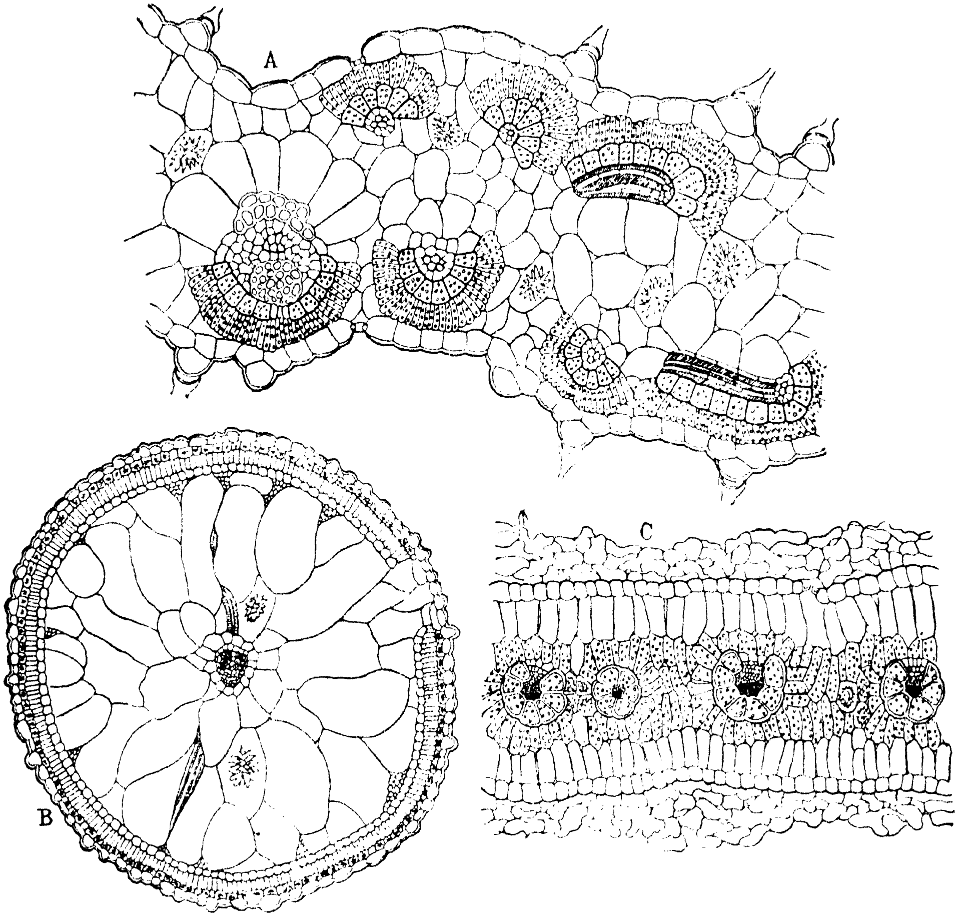


FIG. 262. *CHENOPODIACEAE*
Transverse sections through the leaves of: A, *Chenolea muelleri* (L.) Asch. (syn. *Bassia muricata* All.); B, *Salsola longifolia* Forsk.; C, *Atriplex halimus* L.—After Volkens.

and according to Sabnis (1977) by thin-walled parenchymatous cells in *Haloxylon recurvum* (Wall.) Bunge.

Petiole (Fig. 263 B, E, G, I), in transverse sections through the distal end, exhibiting an arc or cylinder of individually distinct vascular bundles. An adaxially flattened cylinder of bundles noted at Kew in species of *Atriplex* (Fig. 263 I); a variously shaped arc of bundles observed in species of *Axyris*, *Beta* (Fig. 263 E), *Chenopodium* (Fig. 263 G), and *Obione* (Fig. 263 B). **Crystals** often abundant, mostly clustered or in the form of sand, both of these types sometimes being present in a single leaf; octahedra and prisms rare, but recorded in *Bassia hyssopifolia* (Pall.) Volkens and *Camphorosma monspeliaca* Linn. Clustered crystals sometimes situated in large idioblasts in the mesophyll. See also under 'Epidermis'.

An abnormal specimen of *Salicornia herbacea* Linn. with free leaves has been described by Halket (871). In the mesophyll of the leaves of the abnormal plant, the assimilatory tissue was confined to the abaxial side, and the 'cortex' of the stem consisted of the downward continuation of the free parts of the leaves. The peculiar structure of this abnormal plant was held by Halket to support the theory that the primary cortex of the axis is homologous with leaf tissue. This view was previously expressed by de Fraine (555), following a morphological and anatomical study of normal *Salicornia* plants, and by Cooke (458), after making observations on *Salicornia australis* Banks et Sol.

The leaf structure of various species of *Fredolia* (*Anabasis*) and *Haloxylon* has been described in detail by Rosengart-Famel (1949).

AXIS

STEM (Fig. 263 C, D, F, H)

Chiefly noteworthy for exhibiting **anomalous secondary thickening.** Mature stems of all investigated species, in which these become relatively thick, contain numerous vascular bundles, laid down, together with the conjunctive tissue around them, by a succession of rings or arcs of cambium, usually situated in the pericycle, the later ones, according to Cumming (512), sometimes originating in the phloem. This type of anomalous structure recorded by Ulbrich (2311) throughout the family except in the Polycnemoideae (i.e. *Hemichroa*, *Nitrophila*, *Polycnemum*).

The secondary vascular bundles are, in most instances, embedded in the parenchymatous ground-tissue in a concentric, spiral, or irregular manner as seen in transverse sections, but the outline of the individual strands is not always clearly defined owing to the similarity of the ground-tissue of the bundles themselves to the conjunctive tissue between them (Fig. 263 D, F). In extreme examples, e.g. in *Bassia* and *Camphorosma*, transverse sections exhibit alternate zones of woody and thin-walled tissue, the latter being continuous with the phloem groups of the successive rings of bundles. The individual bundles of a single woody zone sometimes tend to be separated from one another by thin- or thick-walled rays of varying width. The apparent medullary vascular strands (Fig. 263 D, H) which are visible in some species are said, in most instances, to be leaf traces. They represent the first bundles to be formed in the stem and are laid down before secondary thickening begins. The first pericyclic cambium produces a layer of pith-like tissue before any secondary bundles are formed, and this sequence of events causes the primary bundles to appear as if they are medullary. The primary bundles sometimes grow in thickness to a considerable extent before the formation of secondary bundles begins, e.g. in species of *Bassia*, *Camphorosma*, *Chenopodium*, *Echinopsilon*, *Kochia*. The course of the vascular bundles has been studied in considerable detail in *Fredolia* (*Anabasis*) by Hauri (921), by Mao (1436) and by Wilson (2437) in numerous members of the family. For further details concerning anomalous secondary thickening see under 'Wood'.

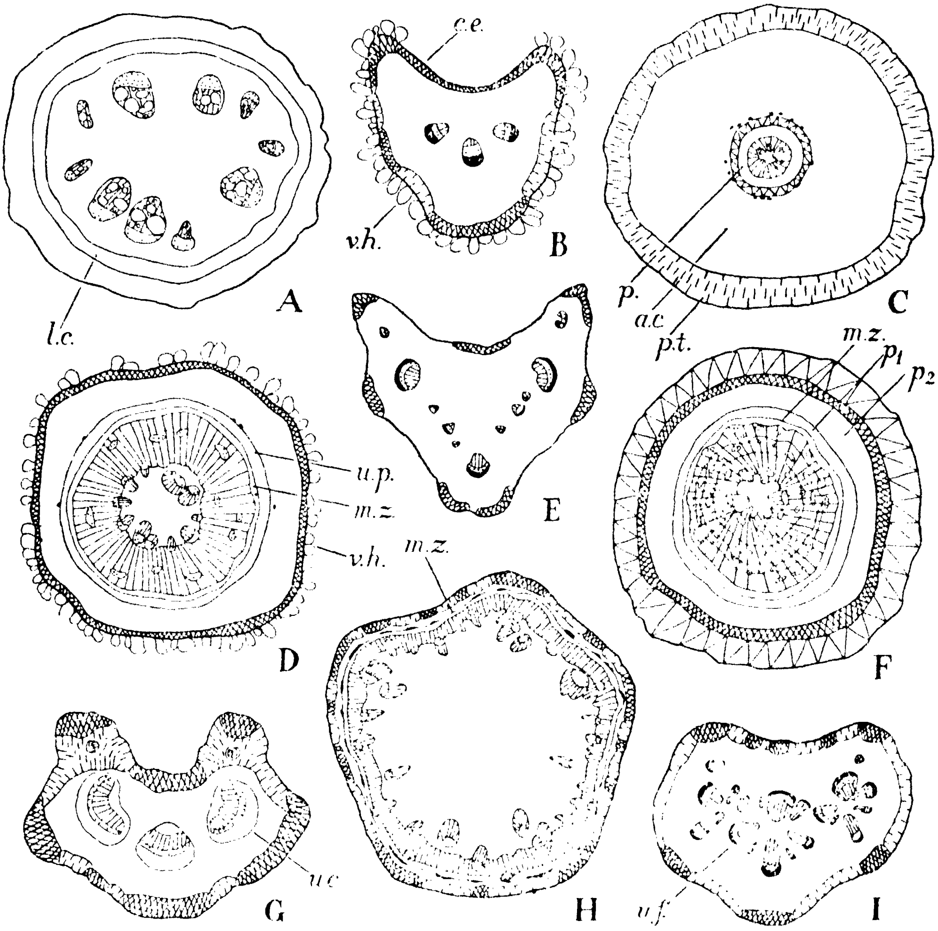


FIG. 263. *BASELLACEAE*, A; *CHENOPODIACEAE*, B–I

A, *Boussingaultia baseloides* H. B. et K. Stem × 18. B, *Obione portulacoides* (L.) Moq. Petiole × 27. C, *Salicornia perennis* (Gouan.) Mill. Young stem × 14. D, *Obione portulacoides* (L.) Moq. Stem × 18. E, *Beta maritima* Linn. Petiole × 9. F, *Salicornia perennis* (Gouan.) Mill. Stem × 23. G, *Chenopodium bonus-henricus* Linn. Petiole × 24. H, *Atriplex hortensis* Linn. Stem × 13. I, *A. hortensis* Linn. Petiole × 15.

a.c. Aqueous primary cortex with small vascular strands. *c.e.* Cutinized epidermis. *l.c.* Lignified cells. *m.z.* Meristematic zone with phloem strands. *p.* Pericycle. This becomes differentiated into *m.z.* p_1 and p_2. p_1 Zone of secondary cortex composed of small cells. p_2 Zone of secondary cortex with conspicuous intercellular spaces. *p.t.* Palisade tissue. *u.c.* Unlignified thickened cells. *u.f.* Unlignified fibres. *u.p.* Unlignified pericycle. *v.h.* Vesicular hairs.

Some of the herbaceous species are provided with collenchymatous ribs. **Stomata** sometimes transversely orientated in relation to the longitudinal axis of the stem, e.g. in *Arthrocnemum indicum* (Willd.) Moq. and *Suaeda nudiflora* Moq. according to Mullan (1571) (see also under 'Leaf', pp. 1076–7). **Cork,** when present, arising in the sub-epidermis in *Camphorosma,* in the primary cortex in species of *Kochia,* internally to the pericyclic fibre strands in the Atripliceae, Salicornieae (Fig. 263 C, F), Salsoleae, Suaedeae. Pericyclic cork sometimes originating from cells intimately associated with, and possibly forming part of, the secondary cambial layers. Cork said to include a proportion of mucilaginous cells in *Haloxylon.* A thick layer of cork, composed of polygonal cells, noted at Kew in old stems of *Salicornia.* Outer part of the primary **cortex** sometimes differentiated as palisade tissue, e.g. in species of *Arthrocnemum, Corispermum, Haloxylon, Salicornia, Salsola, Suaeda.* Sclerosed cells, sometimes showing spiral striations, occur in the palisade chlorenchyma of *Salicornia.* A secondary, aerenchymatous cortex at the base of the main stem, in the upper part of the main root, and in the rhizome of perennial species of *Salicornia* recorded by de Fraine (555) and noted at Kew in the basal parts of the aerial stem in the same genus. **Endodermis** sometimes conspicuous, especially in young stems. Chloroplasts, more numerous in the endodermis and stele than in the cortex, recorded by Mullan (1571) in *Suaeda nudiflora.* Weak strands of fibres sometimes present at the outer limit of the **pericycle.** Long, narrow arcs of fibres noted at Kew in the pericycle of a few species of *Beta* and *Chenopodium.* **Phloem** of *Fredolia* (*Anabasis*) *aretioides* Moq. et Coss. said by Hauri (921) to consist of mucilaginous cells, true sieve tubes being absent. No sieve tubes detected by Cooke (458) in the phloem of *Salicornia australis* Banks et Sol. Large sieve tubes recorded in the phloem of *Chenopodium album* Linn. by Artschwager (38), and very large tubes observed at Kew in *Beta maritima* Linn. **Xylem** usually including vessels with simple perforations (see also 'Wood'). **Crystals** occurring in the same forms as described under 'Leaf' and often abundant. **Oil** recorded by Mullan (1571) in the epidermis and cortex of *Suaeda nudiflora* Moq., and mucilage in the intercellular spaces of the cortex in the same species.

WOOD (Fig. 260 A and C–F)

Vessels small (mean tangential diameter less than 100 μ) and sometimes extremely small (less than 25 μ); typically in groups or clusters on the inner sides of the phloem strands (Fig. 260 A and F); sometimes with a slight tangential pattern, e.g. in *Grayia* and *Sarcobatus,* and occasionally with multiples of 4 or more cells, e.g. in *Chenopodium*; spiral thickening observed or reported (1851, 2158) in some species of *Allenrolfea, Atriplex, Camphorosma, Eurotia, Halocnemum, Halostachys, Haloxylon, Kochia, Noaea, Rhagodia, Sarcobatus,* and *Suaeda*; semi-ring-porous in some species of *Allenrolfea* and *Grayia*; perforations simple; Solereder, quoting Georghieff, refers to scalariform perforation plates with very oblique, almost longitudinal bars in *Axyris amarantoides* Linn. Intervascular pitting alternate, small to minute, sometimes oblong rather than round and often with striations due to coalescent apertures; pits to parenchyma similar. Sometimes with abundant solid contents. Mean member length usually 0·075–0·1 mm. **Parenchyma,** other than the conjunctive, rather sparse, paratracheal, surrounding and mixed with the groups of vessels and sometimes not clearly distinguishable from the conjunctive parenchyma, which usually touches the vessel groups on the abaxial side. Conjunctive parenchyma most typically linking together the phloem strands in broad, but irregular, bands; chambered crystals common on the margins of the bands; with similar crystalliferous strands scattered among the thick-walled fibres that take the place of the bands of conjunctive parenchyma in *Grayia spinosa* (Hook.) Moq. Parenchyma of both types typically storied and with numerous fusiform cells, the conjunctive parenchyma of some species consisting almost entirely of fusiform cells. **Rays** typically absent, but with broad radial sheets of conjunctive parenchyma occasionally joining the successive layers. Solereder refers to rays of varying breadth in the rings of woody tissue in a few genera, e.g. *Camphorosma* and *Echinopsilon*. **Fibres** with small simple pits, walls often very thick, but moderately thin in some species of *Sarcobatus* and *Suaeda*. Mean length 0·2–0·4 mm. **Vascular tracheids** reported (1493) in *Salsola*. **Included (interxylary) phloem** typical; usually of the 'concentric type' (*c. l. circumvallatum*), with the strands of phloem linked by broad, irregular bands of conjunctive parenchyma, but sometimes tending towards the 'foraminate' type; reported by Pfeiffer (1712) to be present in *Acroglochin* Schrad., *Agriophyllum* M. Bieb., *Anabasis* L., *Arthrocnemum* Moq., *Atriplex* L., *Axyris* L., *Beta* L., *Blitum* L., *Camphorosma* L., *Chenolea* Thunb., *Chenopodium* L., *Eurotia* Adans., *Exomis* Fenzl., *Grayia* Hook. et Arn., *Halocnemum* M. Bieb., *Halogeton* C. A. Mey., *Halostachys* C. A. Mey., *Kochia* Roth., *Noaea* Fenzl., *Rhagodia* R. Br., *Salicornia* L., *Salsola* L., *Sarcobatus* Nees., *Spinacia* L., *Suaeda* Forsk., *Teloxys* Moq., *Traganum* Delile and by Messeri (1493) in *Salsola*. The anomaly may be in the form of concentric zones of xylem and phloem or of vascular bundles embedded in fibrous conjunctive tissue. The relation between these 2 types has been investigated by Joshi (1199) and is discussed under Amaranthaceae (see p. 1071). It may be noted that in *Grayia spinosa* (Hook.) Moq. the phloem strands, which in cross-section are narrow radially and wide tangentially, are embedded in fibrous conjunctive tissue that is distinguishable from the fibrous ground tissue surrounding the vessels, by the thicker fibre walls and the inclusion of scattered crystalliferous parenchyma cells, such as are common in the corresponding conjunctive parenchyma that occurs in the other genera. In some genera the phloem strands may be very small in cross-section. (For further particulars concerning anomalous structure, see under 'Stem', p. 1079.)

ANOMALOUS THICKENING, *see under* 'STEM', 'WOOD', *and* 'ROOT'

ROOT

Primary **vascular structure** diarch in *Chenopodium ambrosioides* Linn. (Holm 1007) and *Atriplex babingtonii* Woods (Cumming 512). Vascular system exhibiting the same type of **anomalous secondary thickening** as that in the stem, even in species of which the stems do not grow in thickness sufficiently to exhibit this feature. Concentric rings of bundles recorded in species of *Beta*, *Camphorosma*, *Chenopodium*, *Corispermum*, *Kochia*, *Spinacia*, and spirally arranged vascular strands in species of *Anabasis*, *Atriplex*, *Chenopodium*, *Haloxylon*, *Obione*, *Salicornia*, *Salsola*, *Suaeda*, but neither arrangement is constant throughout a genus. The mode of secondary thickening in the sugar-beet (*Beta vulgaris* Linn. var. *rapa* Dum.) has been described in considerable detail by Seeliger (2078), as well as by Artschwager (see 'Economic Uses'). For secondary thickening in the root of *Atriplex babingtonii* see Cumming's (512) article. A lacunar primary **cortex** recorded by Mullan (1571) in *Arthrocnemum indicum* (Willd.) Moq.

ECOLOGICAL ANATOMY

The ecological anatomy of various members of the family has provided scope for numerous investigations, and many details are to be found in the various papers cited under 'Leaf' and 'Stem'. It is also worthy of note that Keller (1233) demonstrated that the density of stomata was less in the leaves of certain species of *Atriplex* when grown in saline cultures than in leaves of the same species when grown in cultures free from sodium chloride. At the same time crystals of calcium oxalate were more numerous in plants grown in salt-free than in saline cultures.

TAXONOMIC AND PHYLOGENETIC NOTES

The family has many anatomical points in common with others, such as the Amaranthaceae, that are included in the Centrospermae. Wilson (2437) concluded that the medullary bundles of the Chenopodiaceae, like those of the Amaranthaceae, arose by the gradual advance of bundles from the peripheral circle into the pith. This change was thought to have been initiated at the node, whence it extended up and down the stem.

ECONOMIC USES

The most important species is *Beta vulgaris* Linn. of which cultivated varieties with large, white roots are grown for the production of sugar, and other cultivated varieties with red tap-roots for use as a vegetable. Mangolds or Mangold Wurzels are also cultivated varieties of the same species which form an important fodder crop for cattle during the winter. The anatomy of the sugar-beet has been described in very great detail by Artschwager (40, 41, 42), Artschwager and Starrett (44), and Esau (649, 660). According to Artschwager the young root exhibits a diarch protoxylem plate. The primary cambium, which gives rise to the innermost annual ring in the beet, arises in the interstitial parenchyma, except opposite the 2 protoxylem groups where it is derived from the pericycle. The first secondary cambium in the root and lower part of the hypocotyl arises in the phloem parenchyma, whereas, in the upper part of the hypocotyl, it is derived from the pericycle. Practically all of the supernumerary cambiums, from which the 'annual rings' in the mature root are formed, are already laid down when the diameter of the young root is no greater than that of a lead pencil. All of the cambiums are active at the same time. Artschwager (41) attempted to correlate sugar yield with anatomical structure. The same author and Starrett (44) found that, in sugar-beet affected with the curly top disease, the first anatomical symptoms are to be seen when the cells of the pericycle as well as the immature derivatives of the cambium and their nuclei become hypertrophied. Phloem necrosis was noted in plants grown under unfavourable soil conditions (Artschwager, 42). Esau's work on the sugar-beet has been concerned with the ontogeny of the phloem and the structure of plants suffering from mosaic disease. Mosaic disease is less intimately connected with necrosis of the phloem than is the curly top disease. The yellow parts of infected leaves are thinner than the green and also exhibit certain juvenile characteristics.

Other plants of economic importance include Spinach (*Spinacia oleracea* Linn.) which is cultivated for culinary purposes. The fruits of American Wormseed (*Chenopodium ambrosioides* var. *anthelminticum* A. Gray) are used in the preparations of a vermifuge. A detailed, anatomical description of *Chenopodium ambrosioides* Linn. from the Philippines has been published by Santos (1986). This plant is also stated to yield an oil with anthelminthic properties.

Barilla, an impure form of sodium carbonate, was at one time extracted from species of *Salsola* and other members of the family.

Leaves of *Chenopodium* have been used to adulterate commercial samples of *Datura stramonium* Linn. (family Solanaceae), see p. 976.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Agriophyllum, Anabasis, Anthochlamys, Arthrocnemum, Atriplex,* Axyris,* Bassia, Beta,* Camphorosma, Ceratocarpus, Chenolea, Chenopodium,* Corispermum,* Cornulaca, Cycloloma, Echinopsilon, Enchylaena, Eurotia, Fredolia, Grayia, Hablitzia, Halimocnemis, Haloxylon, Hemichroa, Kirilowia, Kochia,* Lophiocarpus, Monolepis, Nitrophila, Noaea, Obione,* Panderia, Petrosimonia, Polycnemum, Rhagodia, Roubieva, Salicornia,* Salsola,* Spinacia, Suaeda,* Teloxys.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Allenrolfea, Atriplex, (Camphorosma), Chenopodium, Eurotia, Exomis, Grayia, (Halocnemum), (Halogeton), (Halostachys), Haloxylon, (Kochia), (Noaea), (Rhagodia), (Salsola), Sarcobatus, Suaeda.

LITERATURE

(i) *On General Anatomy*

Artschwager **38**, **40**, **41**, **42**, Artschwager and Starrett **44**, Baumgärtel **153**, Cooke **458**, Cumming **512**, de Fraine **555**, Esau **649**, **660**, Greenfield **810**, Halket **871**, Hauri **921**, Holm **1007**, Joshi **1199**, Keller **1233**, Krüger **1288**, Mao **1436**, Moser **1563**, Mullan **1571**, Pergola **1688**, Pfeiffer, H. **1708**, Pratt **1739**, Rosengart-Famel **1949**, Sabnis **1977**, Santos **1986**, Seeliger **2078**, Starr **2188**, Ulbrich **2311**, Wilson **2437**, Wirth **2445**, Wood, J. G. **2457**, Zemke **2505**.

(ii) *On Wood Structure*

Chalk and Chattaway **362**, Joshi **1199**, Kanehira **1209**, Messeri **1493**, Pfeiffer, H. **1712**, Record **1843**, **1851**.

214. BASELLACEAE

(FIG. 263 on p. 1080)

SUMMARY

A small tropical family of rather fleshy, twining plants. According to Ulbrich (2309) the aerial organs are annual, but the plants perennate by means of rhizomes which are frequently tuberous or bear tuberous branches. The family differs from the Chenopodiaceae in not having successive zones of secondary vascular bundles, the vascular system of the axis consisting of only a single ring of isolated strands. **Intraxylary phloem** occurs in the larger bundles, which are therefore bicollateral. In the parenchymatous tissues of both leaf and stems there are **mucilaginous cells** which yield a sap, which can be drawn out into fine threads in fractured material. The presence of this mucilaginous material enables the plants to survive very adverse conditions. Ulbrich (2309) cites an occasion on which a species of *Ullucus*, whilst in a plant press, gave rise to axillary tubercles.

LEAF

Hairs stated to be absent. **Stomata** present on both surfaces; rubiaceous. **Mesophyll** including large, spherical, water-storage cells with mucilaginous walls in species of *Anredera*, *Boussingaultia*, &c. **Petiole** of *Basella rubra* Linn. provided with 2 large, nearly median vascular bundles, accompanied by smaller strands on either side; an arc of xylem and phloem occurs in the corresponding position in *Boussingaultia baselloides* H. B. et K. **Crystals** usually clustered, but prisms and octahedra recorded by Solereder in *Basella*. Calcium phosphate occurs in solution in *Basella rubra*, and in the form of sphaerocrystalline masses in material of the same species preserved in alcohol. **Mucilage cells,** see 'Summary'.

AXIS

STEM (Fig. 263 A)

Cork originating in the outer part of the cortex in *Boussingaultia baselloides* H. B. et K. Primary **cortex** sometimes containing mucilaginous cells similar to those in the leaf; the contents in fractured tissue can be drawn out into threads. **Pericycle** including sclerenchyma which is, according to Solereder, weakly developed in *Ullucus*, in the form of an interrupted ring in *Boussingaultia* or of a continuous ring in *Anredera*. A continuous zone of fibres with wide lumina and thin transverse septa noted at Kew in *Boussingaultia baselloides* (Fig. 263 A, *l.c.*). **Vascular system** appearing in transverse sections as a ring of isolated bundles of unequal size. Xylem commonly including vessels 200 μ or more in diameter (Fig. 263 A), with simple perforations. **Intraxylary phloem** recorded in stems with large bundles. Clustered **crystals** common in the unlignified tissues. **Mucilage cells,** see 'Summary'.

ROOT

Including mucilaginous material similar to that in the cortex of the aerial stem.

TAXONOMIC NOTES

The bicollateral bundles which occur in old stems of members of the Basellaceae serve to distinguish this family rather sharply from others included in the Centrospermae. The nearest connexion seems to be with the Portulacaceae, in certain members of which intraxylary phloem has likewise been recorded.

ECONOMIC USES

Tuberous branches of the rhizome of *Ullucus tuberosus* Lozano are used for food in the Andes. The fleshy, mucilaginous leaves of various members of the family have been used locally as vegetables or for medicinal purposes.

GENERA DESCRIBED

Anredera, Basella, Boussingaultia,* Ullucus.

* Represented in the Kew slide collection.

LITERATURE

On General Anatomy
Ulbrich **2309**.

215. PHYTOLACCACEAE

(FIG. 264 on p. 1088; FIG. 265 on p. 1096)

SUMMARY

(i) GENERAL

Herbs and woody plants that occur in the tropics and sub-tropics. Some species are lianes or climbers, whilst *Gallesia integrifolia* (Spreng.) Harms. and *Phytolacca dioica* Linn. attain the stature of trees. Some species of *Agdestis*, *Anisomeria*, and *Phytolacca* possess napiform roots. The most interesting anatomical character is the **anomalous secondary thickening** of the axis, although this is confined to a few genera. It takes the form of the development, in the pericycle, of a succession of zones of vascular bundles, the latter embedded in ground tissue derived from the same meristems. The leaf is commonly dorsiventral, but isobilateral and centric structure have also been recorded. The mostly ranunculaceous but occasionally rubiaceous **stomata** occur on both surfaces of the leaf or are confined to the lower side. **Hairs** are infrequent, and, where they occur, unicellular or uniseriate. In the stem the **cork** is superficial in origin; the outer part of the **pericycle** contains isolated bundles of fibres or a composite and continuous ring of sclerenchyma in most of the investigated species. In the **xylem** the vessel perforations are exclusively simple. **Crystals** are secreted mostly as raphides or styloids, although other types are also known to occur.

(ii) WOOD

Vessels small to large, usually without any marked grouping or pattern, perforations simple, intervascular pitting alternate, minute to moderately large, pits to parenchyma usually similar, sometimes elongated and simple, members of medium length to moderately short. **Parenchyma** predominantly paratracheal, varying from a few cells to complete sheaths round the vessels, occasionally with some diffuse parenchyma; sometimes with fusiform cells in the conjunctive parenchyma. **Rays** up to 2–10 cells wide in woods without anomalous structure, heterogeneous; present also in woods with anomalous structure, but not always clearly distinguishable in size from the interfascicular parenchyma. **Fibres** with simple or bordered pits, moderately short. **Included phloem** of the 'concentric' type present in many of the genera.

LEAF

Usually dorsiventral, but centric structure recorded in species of *Codonocarpus*, *Didymotheca*, and *Gyrostemon*. Isobilateral structure reported by Heimerl (934) to occur in species of *Anisomeria* and *Lophiocarpus*. **Hairs** infrequent, unicellular or uniseriate. **Epidermis,** and also some of the subepidermal cells in the region of the larger veins, said to be mucilaginous in species of *Codonocarpus* and *Gyrostemon.* Epidermal cells containing chlorophyll in *Petiveria.* A single layer of **hypoderm** recorded in species of *Achatocarpus* and *Seguieria,* and 2 layers of rather large hypodermal cells present below the upper surface in *Gallesia integrifolia* (Spreng.) Harms. **Stomata** often confined to the lower surface, but recorded on both sides in species of *Codonocarpus, Didymotheca, Microtea, Petiveria,* and in *Phytolacca dioica* Linn.; ranunculaceous in species of *Achatocarpus, Agdestis, Anisomeria, Barbeuia, Codonocarpus, Didymotheca, Ercilla, Gyrostemon, Microtea, Phaulothamnus, Phytolacca, Seguieria, Stegnosperma, Tersonia*; rubiaceous in species of *Gallesia, Hilleria, Ledenbergia, Monococcus, Petiveria, Rivina,* but neither type of stoma is constant throughout any of these genera. Stomata specially large in *Stegnosperma.* **Mesophyll** always including several layers of palisade cells; in centric leaves either consisting wholly of palisade tissue, e.g. in species of *Gallesia,* or the central part is composed of water-storage tissue, e.g. in *Gyrostemon.* **Midrib** including 6 separate vascular bundles, each supported by fibres and embedded in water-storage tissue, in *Petiveria alliacea* Linn. according to Holm (1070). **Petiole** (Fig. 265 J), in transverse sections through the distal end of material examined at Kew, exhibiting a slightly dissected, moderately deep, crescentic vascular strand accompanied by accessory bundles in the wings in *P. acinosa* Roxb. (syn. *P. esculenta* Van Houtte) and '*Phytolacca clavigera*'.

Crystals in both leaf and axis usually secreted in the form of styloids in species of *Gallesia, Hilleria, Ledenbergia, Monococcus, Petiveria* (styloids very large and arranged vertically to the lamina in *P. alliacea* Linn. according to Holm (1070)), *Rivina, Schindleria, Seguieria, Trichostigma*; as raphides in *Agdestis, Anisomeria, Ercilla, Phytolacca*; present as sphaerites or large clusters in *Barbeuia, Lophiocarpus, Microtea, Stegnosperma.* Special sacs filled with small crystals recorded by Walter (2353) in species of *Gallesia, Monococcus, Rivina, Seguieria, Trichostigma.* Druses, sphaerocrystals, and quadratic solitary crystals occur together in *Achatocarpus* according to Heimerl (936), but raphides and styloids absent from this genus. Crystalloids recorded in *Ledenbergia, Phytolacca,* and *Rivina.* Crystals have not been reported to occur in *Codonocarpus, Didymotheca, Gyrostemon, Microtea, Tersonia.* **Tannin,** according to Walter (2353), secreted in or immediately below the epidermis in *Achatocarpus* and *Gallesia,* and, according to Heimerl (934), in groups of epidermal cells in species of *Barbeuia, Gallesia, Seguieria.*

AXIS

STEM (Fig. 265 K)

Anomalous secondary thickening in the form of successive rings of vascular bundles in the inner parenchymatous portion of the pericycle recorded in species of *Agdestis, Anisomeria, Barbeuia, Gallesia, Petiveria* (root only according to Holm (1070)), *Phytolacca* (stem and root; anomalous structure absent from *P. dioica* Linn. according to Holm (989)), *Seguieria.* Concentric rings of xylem and phloem occur in sufficiently thick stems of *Ercilla, Gallesia, Phytolacca, Rivina, Seguieria.* Anomalous secondary thickening has not been reported as occurring in *Achatocarpus, Codonocarpus, Didymotheca,*

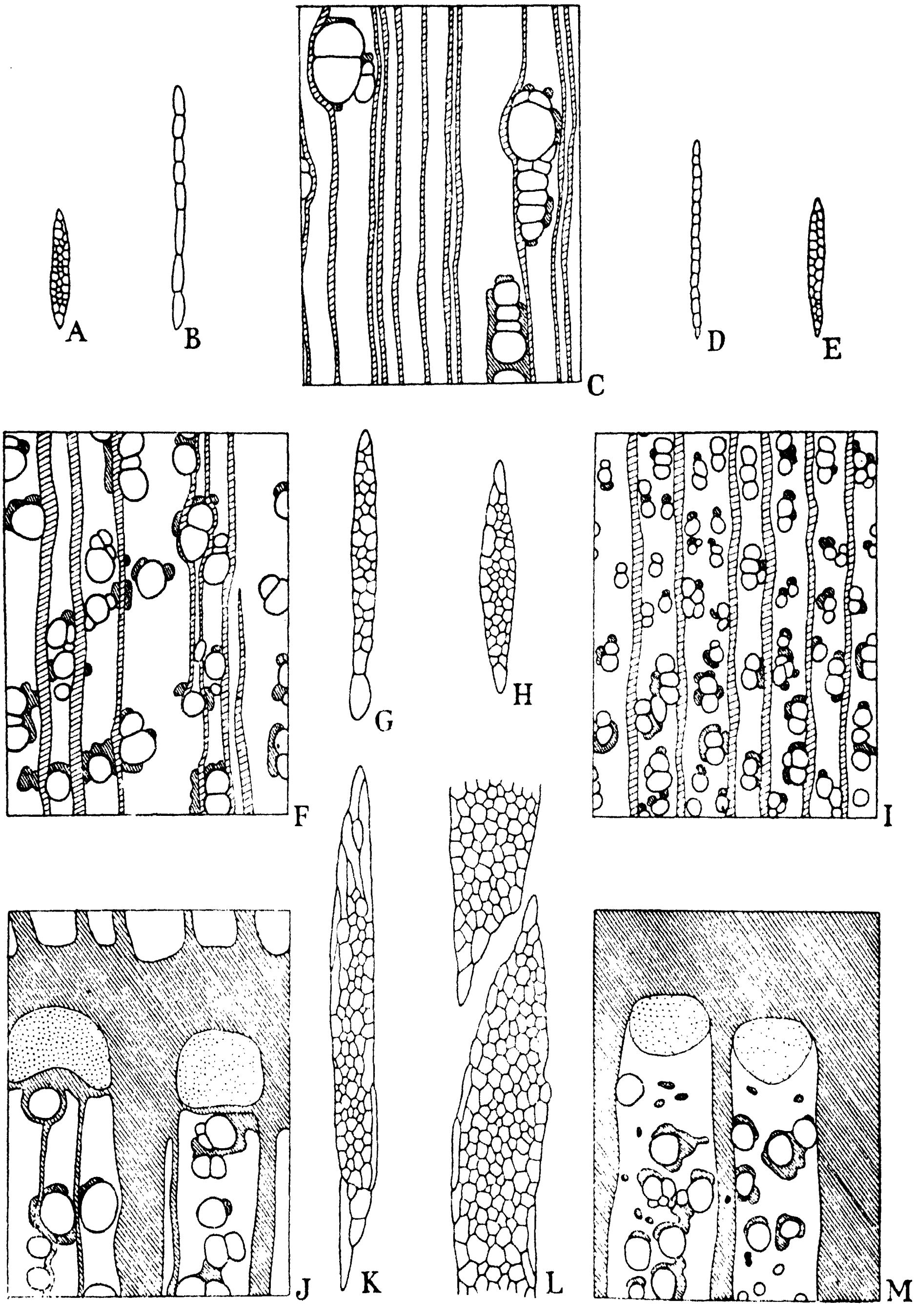


FIG. 264. *POLYGONACEAE*, A–E; *ARISTOLOCHIACEAE*, F–G; *PHYTOLACCACEAE*, H–M

A, *Triplaris surinamensis* Cham. B, *Coccoloba caracasana* Meissn. C, *C. caracasana* Meissn. D, *Ruprechtia fagifolia* Meissn. E, *R. laxiflora* Meissn. F, *Apama siliquosa* Lam. G, *A. siliquosa* Lam. With oil cell. H, *Achatocarpus obovatus* Schinz. I, *A. praecox* Griseb. J, *Seguieria paraguayensis* Morong. K, *Gallesia gorarema* (Vell.) Moq. L, *Gyrostemon ranunculosum* Desf. M, *Rhabdodendron amazonicum* (Benth.) Huber.

Gyrostemon, *Hilleria*, *Ledenbergia*, *Microtea*, *Monococcus*, *Phaulothamnus*, *Rivina*, *Schindleria*, *Stegnosperma*, *Tersonia*, *Trichostigma*. Interfascicular rays broad, generally lignified. For further details concerning anomalous thickening see under 'Wood'.

Epidermis composed of palisade cells in *Seguieria longifolia* Benth. **Cork** arising in the sub-epidermis in species of *Codonocarpus*, *Gallesia*, *Gyrostemon*, *Ledenbergia*, *Petiveria*, *Phytolacca*, *Seguieria*. Primary **cortex** containing a few sclerosed cells; outer part strongly collenchymatous in species of *Phytolacca* (Fig. 265 K). Outer part of the **pericycle** containing isolated bundles of sclerenchymatous fibres in species of *Ledenbergia* and *Rivina*; with a composite and continuous or slightly interrupted ring of usually rather thin-walled sclerenchyma in species of *Achatocarpus*, *Codonocarpus*, *Gallesia*, *Phytolacca*, *Seguieria*. **Phloem** including groups of stone cells and occasional, strongly thickened fibres in *Achatocarpus* according to Heimerl (936). **Xylem** including vessels with simple perforations. **Pith** broad and sometimes becoming hollow in *Phytolacca*. For **crystals** see 'Leaf'. **Tannin** abundant in the cortex, medullary rays, and xylem of *Achatocarpus* according to Heimerl.

WOOD (Fig. 264 H–M)

Vessels usually small (less than 100 μ mean tangential diameter) and sometimes very small (25–50 μ), but sometimes large, according to Record and Hess (1886); varying from almost entirely solitary in some species of *Rhabdodendron* to numerous clusters in *Gyrostemon* and multiples of 2 or 3 cells in *Achatocarpus* (Fig. 264 I), but typically without any pronounced pattern except in *Seguieria*, in which the vessels are often limited to a narrow radial strip on the inner side of each phloem bundle. Mostly 5–20 per sq. mm., but occasionally more numerous and up to about 60 per sq. mm. in *Achatocarpus praecox* Griseb. Solereder refers to spiral thickening in *Anisomeria drastica* Moq., but this feature appears to be absent from other species; fine spirals have been observed in a few vessels in *Gallesia gorarema* (Vell.) Moq. Perforations simple. Intervascular pitting alternate, varying from minute in *Achatocarpus* and *Rhabdodendron* to rather large in *Gallesia* and *Gyrostemon*; occasionally with a tendency to coalescent apertures, e.g. in *Seguieria*. Pits to ray and wood parenchyma usually similar to the intervascular pitting, but often elongated and simple in *Gallesia* and *Gyrostemon* and, according to Solereder, in *Phytolacca*. Mean member length 0·3–0·4 mm. **Parenchyma** typically paratracheal, from a few cells round the vessels, e.g. in *Achatocarpus* (Fig. 264 I), to moderately abundant and aliform, e.g. in *Rhabdodendron macrophyllum* (Spruce) Huber, and with some scattered cells (diffuse) in *Gyrostemon* and *Rhabdodendron*. Strands usually up to 2 or 4 cells. Conjunctive parenchyma variable in type, sometimes, but not typically, containing many fusiform cells; some species of *Gallesia* and *Seguieria* have large crystals that occupy the whole of the lumina of fusiform cells, particularly on the outer fringe of the phloem bundles; raphides reported (959) in *Phytolacca dodecandra* L'Hér. **Rays** not more than 3–4 cells wide in *Achatocarpus*, *Codonocarpus* (2158) and *Rhabdodendron macrophyllum*, up to 10 cells wide in *Gyrostemon ramulosus* Desf.; heterogeneous (Kribs's Type II A and B) in *Achatocarpus*, with 3 or 4 marginal rows of square to upright cells, and with numerous uniseriates that are composed of square to upright cells or of both upright and procumbent cells; almost homogeneous (Kribs's Type I) in *Gyrostemon* and with few uniseriates, which are composed of both procumbent and upright cells. Composed entirely of square and upright cells in *Rhabdodendron macrophyllum*. In *Gyrostemon* some of the rays are very high, while others show evidence of dissection from high rays (Fig. 264 L). In species with anomalous structure true rays are usually present between the radial sheets of interfascicular conjunctive parenchyma, often with an almost complete gradation of widths from the latter to uniseriate rays; all the rays typically composed of both upright and procumbent cells, but sometimes composed of square to upright cells only, e.g. in *Rhabdodendron*; the larger rays sometimes with sheath cells, e.g. in *Gallesia* and *Seguieria*; sometimes containing crystals. **Fibres** usually with small, simple pits; bordered pits observed in *Rhabdodendron macrophyllum*, one specimen of *Gallesia* sp., and *Gyrostemon*, and reported by Solereder in *Microtea* and *Stegnosperma*; Solereder refers to some septate fibres in *Rivina humilis* Linn.; walls moderately thin to very thick. Mean length 0·8–0·9 mm. **Included (interxylary) phloem** of the 'concentric' type (*c. l. circumvallatum*) commonly present, with successive bundles of xylem and phloem repeating the structure of the young stem, separated by tangential bands of conjunctive parenchyma and interfascicular rays (Fig. 264 J and M); reported by Pfeiffer (1712) in *Agdestis*, *Barbeuia*, *Ercilla*, *Gallesia*, *Petiveria*, *Phytolacca*, *Rivina*, and *Seguieria*, to which may be added *Rhabdodendron* spp. except *R. macrophyllum*. Without anomalous structure in *Achatocarpus*, *Hilleria*, *Gyrostemon*, *Ledenbergia*, *Monococcus*, *Rhabdodendron macrophyllum*, *Schindleria*, and *Trichostigma*. For further particulars concerning anomalous structure see under 'Stem' above.

ANOMALOUS STRUCTURE, *see under* 'STEM' *and* 'WOOD'

ROOT

The napiform roots of *Anisomeria coriacea* Don. consist mostly of large parenchymatous cells containing raphides. Centre of the root of this species occupied by the primary vascular tissue, the latter becoming split up by secondary dilation. Several concentric circles of isolated bundles present in the ground-tissue surrounding the vascular tissue at the centre.

TAXONOMIC NOTES

The Australian Gyrostemonaceae have been treated by Heimerl (935) as a separate family from the Phytolaccaceae. The same author also regards the American genera *Achatocarpus* and *Phaulothamnus* as sufficiently distinct to constitute the family Achatocarpaceae. In this connexion it may be noted that *Achatocarpus* shows no anomalous thickening; it includes fibres and stone cells in the phloem, whilst druses, sphaero- and solitary crystals occur together in the same genus.

The wood of *Rhabdodendron* fits very well into this family. Most of the species have the same type of 'concentric' anomalous structure as is characteristic of many of the genera in the Phytolaccaceae and the one species that has normal xylem, *Rhabdodendron macrophyllum* (Spruce) Huber, has wood that very closely resembles that of *Achatocarpus*.

ECONOMIC USES

The root of *Phytolacca americana* Linn. (*P. decandra* Linn.) is used to adulterate that of *Atropa belladonna* (Family Solanaceae, see p. 975). The adulterant can be distinguished by the concentric rings of bundles, formed by anomalous secondary thickening, and by the presence of raphides. The root of *P. americana* has itself been used in medicine, but is now seldom employed. The leaves of *P. americana* have also been used to adulterate those of *A. belladonna*. Apart from the presence of raphides, the adulterant can be distinguished by its ranunculaceous stomata.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Achatocarpus, Agdestis, Anisomeria, Barbeuia, Codonocarpus, Didymotheca, Ercilla, Gallesia, Gyrostemon, Hilleria, Ledenbergia, Lophiocarpus, Microtea, Monococcus, Petiveria, Phaulothamnus, Phytolacca,* Rivina, Schindleria, Seguieria, Stegnosperma, Tersonia, Trichostigma.

(ii) FOR WOOD STRUCTURE

Achatocarpus, (Anisomeria), (Codonocarpus), (Ercilla), Gallesia, Gyrostemon, (Microtea), (Phytolacca),* Rhabdodendron, (Rivina), Seguieria, (Stegnosperma).

* Represented in the Kew slide collection.

LITERATURE

(i) *On General Anatomy*

Heimerl **934**, **935**, **936**, Holm **989**, **1070**, Rowson **2534**, Walter **2353**.

(ii) *On Wood Structure*

Chalk and Chattaway **362**, Hess **959**, Pfeiffer, H. **1712**, Record **1842**, **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**.

216. BATIDACEAE

SUMMARY

The only member of this family is *Batis maritima* Linn., a shrub with a habit somewhat resembling that of the Chenopodiaceae. It is confined to the maritime districts of tropical and sub-tropical America. Each leaf, according to Johnson (1184), bears, concealed within its sheathing base, a pair of stipules, which soon wither. The stipules may function as glands.

LEAF

The following description of the leaf is based mainly on Johnson's (1184) account. Leaf glaucous and fleshy, cylindrical at the distal end, sub-cylindrical in the middle of its length, adaxially grooved and stem-clasping at the base. **Stomata** rubiaceous, with semi-lunar subsidiary cells. **Mesophyll** including 4–5 layers of palisade cells. Two **vascular bundles** enter the base of the leaf, but each immediately bifurcates, the 2 median strands of the 4 thus produced uniting to form a single bundle. The marginal branches of each of the original leaf-traces fork once or twice farther towards the distal end of the leaf, the vascular branchlets finally ending in small groups of tracheids with reticulate pitting, situated just below the palisade tissue. Vessels of the larger vascular strands provided with spiral or annular thickening. **Crystals** clustered and solitary.

AXIS

STEM

Quadrangular, bearing opposite leaves. **Cork** arising on the inside of the bundles of pericyclic fibres. A well-developed phelloderm with abundant intercellular spaces also formed from the phellogen. Solitary **crystals,** sometimes with a corroded appearance, present in the pith, primary cortex, and phloem. **Vascular system** in transverse sections through a typical internode appearing as 3–5 bundles corresponding to each angle of the stem, the vascular strands being separated from one another by multiseriate rays. A single but smaller vascular bundle also present opposite each lateral surface of the stem.

According to Solereder the 2 small bundles on opposite sides of the stem decrease in size as they are traced upwards to the next node above; they first lose their xylem, and after that their phloem, while, in the neighbourhood of the node, even the pericyclic fibres, which accompany the bundles, disappear. These bundles do not, therefore, extend into the petiole, which is supplied by the 2 nearest of the bundles in the angles of the stem.

Solereder also states that the **xylem** is composed of circular, thick-walled vessels up to 30 μ in diameter and provided with simple perforations; exclusively paratracheal parenchyma; broad rays; small, thick-walled fibres with distinctly bordered pits.

TAXONOMIC NOTES

Batis appears to occupy a somewhat isolated taxonomic position. Its possible affinities have been summarized by Uphof (2314) and Johnson (1184).

GENUS DESCRIBED

Batis.

LITERATURE

On General Anatomy

Johnson **1184**, Uphof **2314**.

217. POLYGONACEAE

(FIG. 264 on p. 1088; FIG. 265 on p. 1096)

SUMMARY

(i) GENERAL

A cosmopolitan family consisting mostly of herbs, but including some shrubs or small trees and a few climbers. Some species of *Polygonum* are remarkable for their very rapid vegetative growth. Other members of the family are xerophytes and exhibit **biological specializations** such as phylloclades, or, in other species with reduced leaves, the cylindrical stem becomes the chief assimilatory organ. Some of the perennial species have creeping or large fleshy rhizomes, e.g. in *Rheum*. There is usually a very characteristic membranous sheath or **ochrea** at the base of the petiole, which is described below under 'stipules'. The **leaf** is dorsiventral to centric. Glandular **hairs** occur widely, and are sometimes aggregated in depressions in the leaf surface or petiole, and then constitute **extra-floral nectaries. Secretory cells** or **cavities** sometimes occur in *Polygonum* and may appear as transparent dots in the leaf. In the **stem,** sub-epidermal strands of collenchyma, sclerenchyma, or occasionally small accessory vascular bundles provide an interesting feature. **Cork** usually arises in the epidermis. The **pericycle** contains sclerenchyma in the form of a continuous ring or as isolated bundles of fibres. In the **xylem,** vessels vary in arrangement and size, and their perforations are always simple. **Anomalous structure** occurs in a few species and usually exhibits one of the following forms. (i) Internal or medullary bundles. (ii) Intraxylary phloem. (iii) Interfascicular phloem strands. **Crystals** are mostly clustered, although solitary ones also occur. **Tannin** is also widely distributed in the family, and sometimes accumulates in special sacs in the parenchymatous tissues of the axis.

(ii) WOOD

Vessels mostly medium-sized, often with moderately numerous multiples of 4 or more cells, sometimes tending to be ring-porous, spiral thickening sometimes present, perforations simple, intervascular pitting alternate, very small to medium-sized, vestured, pits to parenchyma usually similar, members of medium length to moderately short. **Parenchyma** paratracheal, scanty to narrowly vasicentric. **Rays** typically uniseriate or up to 2–3 cells wide and low, but occasionally wide and high, homogeneous to slightly heterogeneous. **Fibres** typically septate, with simple pits; commonly crystalliferous; moderately to very short.

LEAF

Usually dorsiventral, but centric structure recorded by Gross (828) in species of *Chorizanthe*, *Eriogonum*, *Harfordia*, *Muehlenbeckia*, *Polygonum*, *Pteropyrum*, *Symmeria*, *Triplaris*. Mesophyll of dorsiventral leaves usually including 2–4 layers of palisade tissue. **Hairs.** The following information has been recorded mainly by Gross (828).

A. Non-glandular hairs. (i) Papillae and stiff peg-like hairs present in species of *Coccoloba*, *Fagopyrum*, *Muehlenbeckia*, *Oxygonum*, *Polygonum*, *Rheum*, and *Rumex* (see also under 'Epidermis' on p. 1094). (ii) Long, unicellular hairs present in all of the Eriogonoideae; absent from the Coccoloboideae. (iii) Uniseriate trichomes present in *Antigonon*, *Brunnichia*, *Coccoloba*, *Fagopyrum* (pro parte), *Leptogonum*, *Podopterus*, *Ruprechtia*, *Symmeria*, *Triplaris*. (iv) Unicellular hairs with multicellular bases in *Persicaria* section *Aconogonum*. (v) Bristle hairs in *Cephalophilum*, *Persicaria* sections *Eupersicaria*, and *Tovara*. (vi) Clustered hairs in *Persicaria* section *Echinocaulon*. (vii) Stellate hairs recorded by Holm (995) in *Polygonum arifolium* Linn.

B. Glandular hairs. (i) Consisting of a basal cell, a neck cell, and a head of 2 or more cells in *Antigonon*, *Eriogonum*, and *Oxytheca*. (ii) Sessile glands in species of *Polygonum*, *Rheum*, and *Rumex*. (iii) Short-stalked, peltate glands in *Coccoloba*, *Podopterus*, *Symmeria*, *Triplaris*. (iv) Superficial mucilage glands present on young leaves of *Brunnichia*, *Coccoloba*, *Fagopyrum*, *Persicaria*, *Polygonum*, *Rheum*, *Rumex*. Concentrations of glands in depressions in the leaf surface or on the petiole form **extra-floral nectaries** in species of *Fagopyrum*, *Muehlenbeckia*, and *Polygonum*. The extra-floral nectaries in various species of *Polygonum* have been investigated from the structural and physiological standpoints by Salisbury (1983). He concluded that the nectaries are in the nature of hydathodes whose action is dependent on osmosis. No evidence was found that the nectaries are visited by ants or any other animal organisms.

Epidermis on the upper surface, especially in xerophytic species, often including cells with mucilaginous walls. Epidermis papillose on both surfaces in *Calligonum polygonoides* Linn. and on the upper side only in *Polygonum plebeium* R. Br. according to Sabnis (1977). A papillose epidermis also recorded by Holm (995) in *P. virginianum* Linn. (see also under 'Hairs' on p. 1093). Large water-storage cells occur in the epidermis of the last species. **Stomata** usually present on both surfaces or confined to the lower side, although occurring exclusively on the upper surface in floating leaves of *P. amphibium* Linn.; nearly always ranunculaceous except in *Coccoloba* which has distinct subsidiary cells; rubiaceous in *Oxytheca* and *Triplaris*. Subepidermal bundles of sclerenchyma frequent according to Gross (828) in several, mostly xerophytic species of *Polygonum*. **Hypoderm** is differentiated in *Coccoloba*.

Midrib, according to Gross (828), projecting only slightly above the surface of the leaf or wholly embedded in the mesophyll in species of *Atraphaxis*, *Calligonum*, *Muehlenbeckia* (section *Andinia*), *Polygonella*, *Polygonum* (except the section *Paronychia*), *Pteropyrum*, *Rumex* (section *Acetosa*). Midrib in other genera much more prominent. Vascular bundles of the **veins** accompanied by sclerenchyma towards one or both surfaces in species of *Calligonum*, *Eriogonum*, *Hollisteria*, *Nemacaulis*, *Oxygonum*, *Oxytheca*, *Polygonum*, *Thyrsanella*, and towards both surfaces in species of *Atraphaxis*, *Brunnichia*, *Coccoloba*, *Leptogonum*, *Podopterus*, *Ruprechtia*, *Triplaris*, the upper and lower groups of sclerenchyma becoming united to form a sheath in species of *Brunnichia*, *Coccoloba*, *Leptogonum*, *Ruprechtia*. Vascular bundles sheathed by collenchyma instead of sclerenchyma in species of *Emex*, *Fagopyrum*, *Oxyria*, *Persicaria*, *Polygonum*, *Rheum*, *Rumex*. Vascular bundles sheathed by tanniniferous cells in *Polygonum plebeium* according to Sabnis (1977) and in *Muehlenbeckia axillaris* Walp. according to Betts (187).

Petiole (Fig. 265 A, B, C, E, G), in transverse sections through the distal end of material examined at Kew, exhibiting the following range of vascular structure. (i) An adaxially flattened circle of widely spaced collateral bundles, the median strand towards the upper surface being much larger than the remainder in species of *Polygonum* (Fig. 265 G) and *Rumex* (Fig. 265 E). (ii) Similar to (i) but with the bundles more congested in the thin petiole of '*Ruprechtia cordifolia*'. (iii) A deep crescent of about 11 collateral bundles surrounding 2 central strands with their xylem groups directed towards one another observed in *Fagopyrum cymosum* Meissn. (Fig. 265 B). (iv) Numerous scattered bundles, mostly collateral in structure but including a proportion of bicollateral strands and others consisting of a central phloem and 2 peripheral xylem regions, in *Rheum* (Fig. 265 A). (v) A slightly dissected, adaxially flattened vascular ring, but with the adaxial and abaxial portions fairly well separated from one another in *Atraphaxis* (Fig. 265 C). Petiolar vascular strands seldom strongly supported by fibres in the pericyclic region; fibres unlignified when present. **Secretory elements.** Cavities surrounded by low epithelial cells, and appearing as transparent dots in the leaf, stated by Solereder to occur in a few species of *Polygonum*. Tannin often present in the tissues, particularly amongst species from desert regions. **Crystals** often abundant, mostly clustered, but solitary types also occur.

Small anatomical differences between 'Sun' and 'Shade' leaves of 2 climbing species of *Muehlenbeckia* from New Zealand have been described by Bird (199).

STIPULES

Stipules of species of *Fagopyrum*, *Polygonum*, *Rheum*, *Rumex* chiefly noteworthy for the following types of **mechanical tissue,** one or more occurring in an individual species. (i) Thickened epidermis. (ii) Collenchyma developed on the adaxial side in *Polygonum aviculare* Linn. or on the abaxial side in *P. divaricatum* Linn. The whole of the ground-tissue collenchymatous in *P. hydropiper* Linn. and *Rheum*. (iii) Sub-epidermal strands of sclerenchyma in species of *Polygonum*. Palisade tissue absent. **Stomata** rare.

AXIS

STEM (Fig. 265 D, F, H, I)

Sub-epidermal strands of collenchyma (Fig. 265 F) or, more rarely, of sclerenchyma (Fig. 265 H) (e.g. in species of *Calligonum* and *Polygonum*) frequent, sometimes extending into ribs on the stem surface. Species with each of these types of mechanical tissue have been listed by Gross (828). Stone cells recorded by Sabnis (1977) in the ribs of *Calligonum polygonoides* Linn. and *Polygonum plebeium* R. Br. The angles of the stem in other cases, e.g. in species of *Antigonon* and *Rumex*, occupied by small vascular strands. **Cork** usually arising in the sub-epidermis, but pericyclic in species of *Atraphaxis*, *Calligonum*, *Harfordia*, and *Pteropyrum*. Cork cells usually thin-walled, but alternate layers of cells with thick and thin walls respectively recorded in *Ruprechtia*. Tangential walls strongly thickened in species of *Harfordia*, or with horseshoe-shaped thickenings in *Coccoloba*. Cork cells with mucilaginous outer membranes recorded by Lemesle (1352) and earlier investigators in *Atraphaxis* and *Calligonum*. Primary **cortex** of *Calligonum* said by Lemesle (1352) to include water-storage tracheids, some being continuous with accessory cortical vascular bundles and others apparently unconnected with the rest of the conducting system. Stone cells present in the cortex of *Triplaris*. Cortex frequently assimilatory (Fig. 265 F, H).

Endodermis frequently well defined, especially, according to Gross (828), in species of *Antigonon*, *Atraphaxis*, *Brunnichia*, *Calligonum*, *Coccoloba*, *Eriogonum*, *Harfordia*, *Koenigia*, *Muehlenbeckia*, *Nemacaulis*, *Oxygonum*, *Oxyria*, *Oxytheca*, *Podopterus*, *Polygonum*, *Pterostegia*, *Rheum*, *Rumex*, *Triplaris*.

Pericycle, in all investigated species, containing a continuous to slightly interrupted ring or isolated bundles of sclerenchyma. The ring of pericyclic

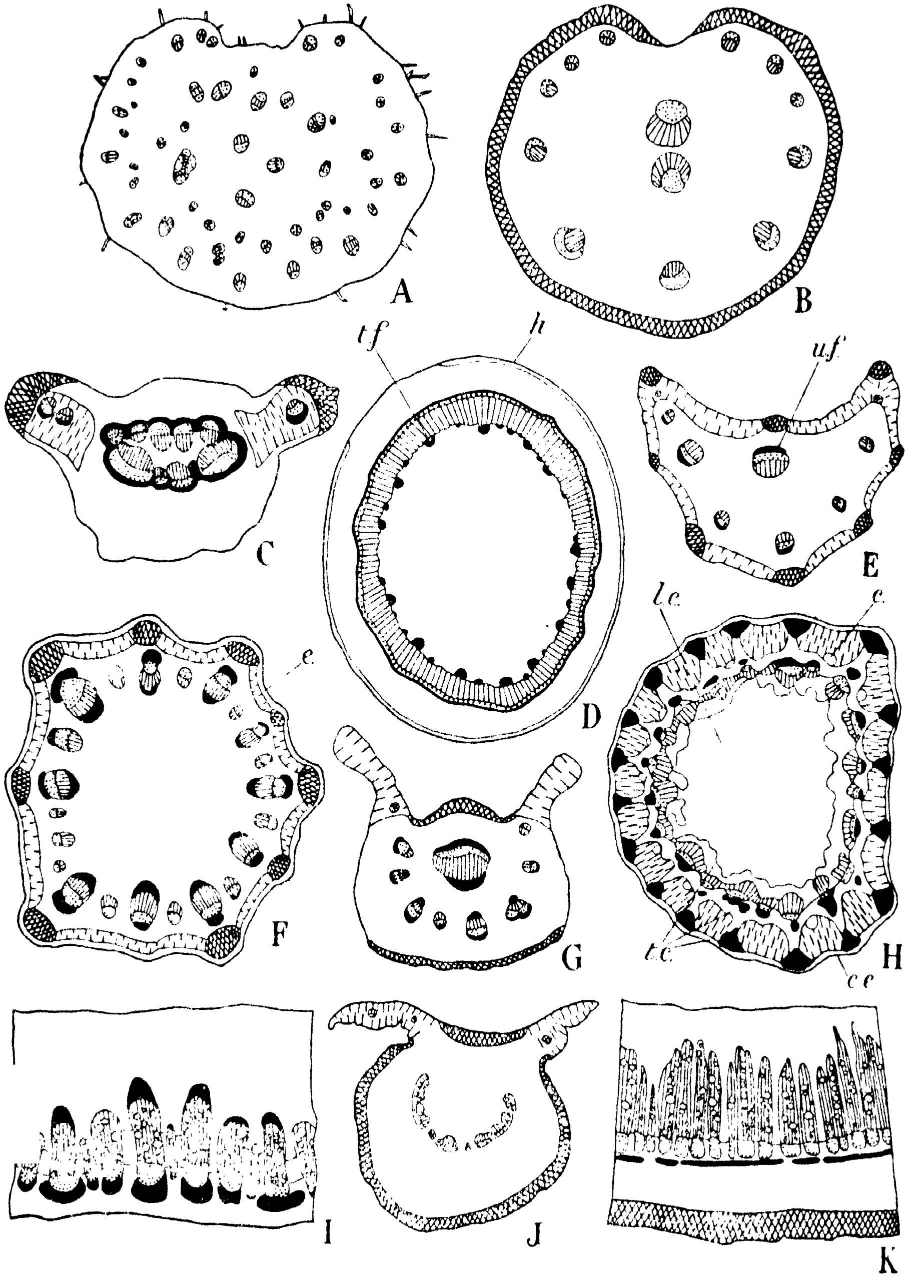


FIG. 265. *POLYGONACEAE*, A–I; *PHYTOLACCACEAE*, J–K

A, *Rheum pichonii* Pierre. Petiole × 5. B, *Fagopyrum cymosum* Meissn. Petiole × 21. C, *Atraphaxis muschketowii* Krassr. Petiole × 36. D, *Coccoloba uvifera* Linn. Stem × 9. E, *Rumex obtusifolius* Linn. Petiole × 15. F, *R. obtusifolius* Linn. Young stem × 19. G, *Polygonum cuspidatum* S. et Z. Petiole × 10. H, *P. equisetiforme* Sibth. et Sm. Young stem × 38. I, *P. sachalinense* Maxim. Portion of stem × 9. J, *Phytolacca acinosa* Roxb. Petiole × 9. K, *P. acinosa* Roxb. Portion of stem × 4.

c. Cluster crystal. *c.e.* Cutinized epidermis. *e.* Epidermis containing tannin. *h.* Hypodermis. *l.c.* Large cells mostly free from tannin. *t.c.* Tanniniferous cells. *t.f.* Thin-walled fibres. *u.f.* Unlignified fibres.

fibres is frequently broad in *Polygonum*, especially in those large herbaceous species which grow very rapidly, where the phloem strands are sometimes partly surrounded by fibres (Fig. 265 I). **Vascular bundles** at first more or less widely separated by broad primary rays, especially in herbaceous species, but later forming a continuous cylinder of xylem traversed by narrow rays in species in which the secondary xylem is well developed. Vessels varying considerably in diameter in different species, a mixture of large and small types sometimes occurring together in a single stem. Large vessels especially characteristic of the species of *Polygonum* which are remarkable for their very rapid growth; sieve tubes also specially large in these species. Vessels with simple perforations. **Intraxylary phloem,** see under 'Anomalous Structure' on p. 1098.

Pith sclerotic and persistent in species of *Atraphaxis*, *Coccoloba*, *Leptogonum*, *Nemacaulis*, *Podopterus*, *Ruprechtia*, *Symmeria*, *Triplaris*; becoming hollow in species of *Antigonon*, *Brunnichia*, *Eriogonum*, *Fagopyrum*, *Oxygonum*, *Oxytheca*, *Polygonum*, *Rumex*, *Triplaris*. A specially wide pith noted at Kew in species of *Fagopyrum*, *Muehlenbeckia*, and *Rheum*. Bundles or a continuous zone of fibres present at the margin of the pith in species of *Campderia*, *Coccoloba*, *Emex*, *Oxyria*, *Podopterus*, *Pteropyrum*, *Rumex*, *Triplaris*, and other genera. **Crystals** common and often abundant; mostly clustered and often very large, less frequently solitary; crystal-sand also recorded by Gross (828) in the Coccoloboideae.

Secretory elements. Tanniniferous cells very common and often abundant. Elongated sacs, with brown gelatinous contents, sometimes attaining a length of 12 cm. or more, but appearing very similar to the neighbouring cells in transverse sections, recorded in the parenchymatous tissues and phloem of numerous species of *Polygonum*.

The stem structure of numerous species of *Calligonum* has been examined and described in detail by Lemesle (1352).

PHYLLOCLADES

Phylloclades of *Polygonum platycladum* F. v. Müll. exhibit the following features. Cortex consisting of groups of 2 or 3 layers of palisade tissue, bounded on the inside by a zone of sclerenchymatous fibres, the latter also extending to the epidermis at intervals and thus forming arcs around the assimilatory tissue. Small vascular bundles present in the assimilatory tissue.

ASSIMILATORY STEMS

The assimilatory stems of certain species of *Calligonum* and *Polygonum*, that have reduced leaves and occur in desert regions, exhibit the structure shown in Fig. 265 H. The presence of semicircular groups of accessory vascular bundles around the fibre strands in the cortex is a notable feature of *C. comosum* L'Hérit., as well as of the numerous other species of this genus examined by Lemesle (1352). See also under 'Anomalous Structure' on p. 1099.

ANOMALOUS STRUCTURE

(i) **Internal bundles.** The development, structure, and course of the internal vascular bundles in various species of *Rumex* have been studied by

Maheswari (1415), Maheswari and Balwant Singh (1417), and Joshi (1198). In *Rumex crispus* Linn. the internal bundles are enclosed within the same sclerenchymatous sheaths as those surrounding the strands which constitute the normal (outer) vascular ring. The internal bundles arise from the inner ends of the procambial strands which give rise to the normal ring of vascular strands. They are not, according to Maheswari, formed by the differentiation of pith cells as was previously supposed. The internal bundles at first consist only of phloem, but a cambium subsequently arises on the outside and produces secondary xylem externally and secondary phloem internally. Still later, the xylem extends along the sides of, and eventually surrounds, the initial phloem strands. The xylem of the internal bundles is, therefore, wholly secondary whilst the phloem is partly primary and partly secondary. Additional internal bundles may arise later than, and in the same way as, the first. In *R. crispus* they develop most extensively towards the stem apex, show a gradual diminution at lower levels and are absent from the basal region. Young plants likewise have no internal bundles, which are also absent from the petioles, where, however, the vascular system consists of scattered strands. The acquisition of internal bundles is believed by Maheswari to be a recent phylogenetic development, an idea supported by the fact that they are known to occur only in species of *Rumex* with high chromosome numbers. Joshi (1198) also concluded that those perennial species of *Rumex* which have no internal bundles are the oldest from the phylogenetic standpoint. These species are thought to have given rise to perennial forms with internal bundles and annuals without them, the annuals possibly having lost the internal strands during their evolution from perennial forms.

According to Joshi (1198) the mode of development of the internal bundles as well as of those of the normal ring is, in *R. orientalis* Bernh., similar to that in *R. crispus*, since most of them at first consist of phloem only, the xylem being wholly secondary in origin. *R. orientalis* differs from *R. crispus* in having internal bundles that extend to the base of the plant, and which are visible even in the hypocotyl of seedlings. The internal bundles, in any one internode of *R. orientalis*, consist partly of downward extensions of the internal bundles of the internode above, partly of adaxial bundles from lateral branches of the stem, and partly of bundles of the normal ring in the internode above.

The vascular system in the inflorescence axis of *R. patientia* Linn. is somewhat complex since it is partly composed of bundles, of which some are inversely orientated, and partly of centric (amphivasal) strands. This species has been examined quite recently by Maheswari and Balwant Singh (1417), who report that 2 or 3 internal bundles are sometimes associated with a single bundle of the normal ring. The same authors have also pointed out that in *Rheum* the internal bundles are not included within the same fibre-masses as those of the normal ring. They are, therefore, more truly 'medullary' than those in *Rumex*. It is claimed that the bundle system in *Rheum* has been derived from the *Rumex* type.

(ii) **Intraxylary phloem.** This has been recorded in *Centropodium* and *Emex spinosa* Campd., but its presence in the last species was not confirmed by Gross (828).

(iii) **Interfascicular phloem** strands occur in *Emex*. These arise between the phloem groups of the ordinary vascular bundles of the stem and become connected with them at the nodes.

(iv) **Semicircular groups of vascular bundles** occur around the fibre strands in the cortex of all of the numerous species of *Calligonum* examined by Lemesle (1352). (See also under 'Assimilatory Stems', p. 1097.)

WOOD (Fig. 264 A–E)

Vessels mostly medium-sized (100–200 μ mean tangential diameter), but sometimes very small (25–50 μ), e.g. in *Eriogonum* and *Neomillspaughia*; solitary and in small multiples, and commonly with multiples of 4 or more cells, in *Coccoloba* (Fig. 264C), *Eriogonum*, *Gymnopodium*, and *Neomillspaughia*; in clusters in *Symmeria*; fewer than 5 per sq. mm. in some species of *Ruprechtia* and *Triplaris*, but typically more numerous; ring-porous or semi-ring-porous in some species of *Calligonum*, *Eriogonum*, and *Ruprechtia*; spiral thickening observed or reported in some species of *Calligonum*, *Chorizanthe* (2158), *Coccoloba* (1851), *Eriogonum*, *Muehlenbeckia* (1851), *Ruprechtia* (1851), and *Triplaris* (2158). Perforations simple. Intervascular pitting alternate, medium-sized to very small, e.g. in *Eriogonum*, *Gymnopodium*, and *Symmeria*; vestured (78); pitting to ray and wood parenchyma cells similar, except in *Neomillspaughia* and *Ruprechtia fagifolia* Meissn., which have some large pits. Tyloses abundant in *Triplaris*. Mean vessel member length usually 0·3–0·5 mm., but shorter, according to Messeri (1493), in *Calligonum*. **Parenchyma** rather sparse, paratracheal, varying from a few cells to a complete sheath round each vessel; with some scattered crystalliferous strands in *Neomillspaughia* and, according to Williams (2430), in *Coccoloba* p.p.; vasicentric and diffuse, according to Messeri (1493), in *Calligonum comosum* L'Hérit.; tending to be storied in *Calligonum*. **Rays** exclusively uniseriate or nearly so in *Coccoloba*, *Eriogonum*, and *Ruprechtia* p.p.; typically 2–3 cells wide in the other genera but up to 5 cells in *Gymnopodium* and 10 cells or more in *Symmeria*; multiseriate rays less than 1 mm. high, except in *Gymnopodium* and *Symmeria*; uniseriates few to numerous, usually composed entirely of procumbent cells; 7–19 rays per mm.; homogeneous (Kribs's Types I and III) in *Neomillspaughia*, *Ruprechtia*, and *Triplaris* and with only 2 or 3 marginal rows of square or upright cells in the other genera; composed entirely of square or upright cells in *Coccoloba caracasana* Meissn. Cells typically filled with dark contents. According to Houlbert (2158) rays are absent from *Chorizanthe paniculata* Benth. **Fibres** with small, simple pits, mostly in the radial walls. Septate, except in *Calligonum* and *Eriogonum*. Walls thin. Commonly crystalliferous, the crystals chambered and separated by septa, e.g. in *Coccoloba caracasana*, *Podopterus* (1886), *Ruprechtia*, and *Triplaris*; the nature of these crystalliferous fibres is discussed by Milanez (1526); according to Kribs (1283) the crystalliferous fibres in *Triplaris surinamensis* Cham. occur in irregular concentric layers that under a lens look like indistinct bands of parenchyma. Mean length usually about 0·7 mm., but, according to Messeri (1493), about 0·45 mm. in *Calligonum*.

ECONOMIC USES

The botanical origin of the rhubarb used in medicine has been much discussed, but it now seems to be generally agreed that the official drug consists of the peeled and dried rhizomes of *Rheum palmatum* Linn. and *R. officinale* Baillon, both obtained from China and Tibet. There are various substitutes and adulterants, which include English rhubarb, derived from *R. officinale* and *R. rhaponticum* Linn., and Indian rhubarb derived from *R. emodi* Wallich. Various species of *Rumex* have also been substituted.

Solereder gives the following particulars concerning the rhizome structure in *Rheum officinale* Baill. which is known to be similar to that of related species. In the tuberous branches of the rhizome of *R. officinale* the collateral leaf-trace strands form a normal vascular ring enclosing a pith, which subsequently increases in size. In a young branch of the rhizome the pith is traversed by a complete network of anastomosing strands of phloem, arranged in transverse zones, following closely upon one another and corresponding to the nodes; these strands unite the leaf traces, and are also connected with one another by bundles which traverse the internodes either in a vertical or oblique direction, and mostly run in the neighbourhood of the xylem ring. Around each of these phloem strands a cambial ring is produced at an early stage and gives rise to rays of phloem on its inner, and rays of xylem with abundant parenchyma on its outer side, whilst between the rays of xylem and phloem medullary tissue is laid down, the cells of which become filled with red or yellow colouring matter which turns more intensely red or pink when treated with alkali. Thus the streaks that are visible in the mature rhizome represent medullary vascular bundles with peripheral xylem. The vascular structure of the root is normal. Both rhizome and root can be recognized microscopically by the 2- to 5-compound starch grains up to about 30 μ in diameter; the abundant cluster crystals in the parenchymatous ground-tissue; the pitted vessel members with unlignified walls; the red or yellow colouring matter in the medullary ray cells which becomes more intensely coloured when treated with caustic soda; the absence of fibres and sclerotic cells. For further particulars concerning rhubarb as well as its substitutes and adulterants see Wallis's (2348) detailed account of this drug, and the articles by Hosseus (1086), Plaut (1731), Rosenthaler and Kiene (1955), and Tunman (2293).

Other economic plants in the Polygonaceae include Buckwheat (*Fagopyrum esculentum* Moench.) which is cultivated in temperate regions for the sake of its edible seeds which can be ground into flour, and the Seaside Grape of Jamaica (*Coccoloba uvifera* Linn.) which has edible but astringent fruits. Tannin has been extracted from the roots of species of *Rumex*.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Antigonon, Atraphaxis,* Brunnichia, Calligonum, Campderia, Chorizanthe, Coccoloba,* Emex, Eriogonum, Fagopyrum,* Harfordia, Hollisteria, Koenigia, Leptogonum, Muehlenbeckia,* Nemacaulis, Oxygonum, Oxytheca, Persicaria, Podopterus, Polygonella, Polygonum,* Pteropyrum, Pterostegia, Rheum,* Rumex,* Ruprechtia,* Symmeria, Triplaris.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Calligonum, (Chorizanthe), Coccoloba, Eriogonum, Gymnopodium, (Muehlenbeckia), Neomillspaughia, (Podopterus), Ruprechtia, Symmeria, Triplaris.

LITERATURE

(i) *On General Anatomy*

Betts 187, Bird 199, Foweraker 703, Gross 828, Hector 929, Holm 995, Hosseus 1086, Joshi 1198, Lemesle 1352, Maheswari 1415, Maheswari and Balwant Singh 1417, Mitra 1543, Plaut 1731, Rosenthaler and Kiene 1955, Sabnis 1977, Salisbury 1983, Tunman 2293, Wallis 2348.

(ii) *On Wood Structure*

Bailey 78, Benoist 170, Betts 188–9, Burgerstein 312, Kanehira 1209, Kribs 1283, Messeri 1493, Milanez 1526, Pfeiffer, H. 1712, Pfeiffer, J. Ph. 1713, Record 1783, 1843, 1851, Record and Hess 1886, Record and Mell 1894, Williams 2430.

218. PODOSTEMACEAE

SUMMARY

A peculiar family, consisting of tropical, aquatic plants which resemble some of the Bryophyta or Phaeophyceae in general appearance. They are mostly annuals which grow attached to rocks and stones, usually in rapidly flowing water or in cascades, but generally flower and fruit above the water during periods of relatively low rainfall. The vegetative body of the plants consists of a thallus which, in some species, is differentiated into portions which roughly correspond to stems and leaves in superficial appearance. In other species the plant body has the form of a flat thallus which adheres firmly to the substratum on which the plant grows. The plants are attached to the substratum either by masses of specialized, hair-like structures which originate as extensions of the epidermal cells, or by more complex organs which superficially resemble the attachment organs of algae of the *Laminaria* or *Fucus* types. The nature of the tissues into which the plant body is differentiated varies considerably according to the habit of the individual species, and it is therefore very difficult to generalize concerning their internal organization. It is noteworthy, however, that intercellular **air spaces** seldom occur, which is unusual in plants living in aquatic habitats. Intercellular spaces have, however, been recorded by Matthiesen (1456) in a few species of *Apinagia* and *Rhyncholacis*. **Mechanical tissue,** when present, is usually in the form of collenchyma, which is especially well developed around the vascular elements. In certain parts of the plant body of the larger species, the collenchyma becomes converted to sclerenchyma in the form of lignified, prosenchymatous elements with slit-like pits. The mode of transformation of collenchyma to sclerenchyma has been investigated by Went (2411). Another important microscopical character is the occurrence of **silica bodies,** especially in the superficial tissue of the thallus. In some species these are sufficiently numerous to form a kind of armour or carapace which prevents the plant from collapsing in times of drought. In other species, including some of those belonging to the same genera, the silica bodies are much less numerous, so that the plants contract considerably when drying. **Hairs** have been recorded on the leaves of species of *Apinagia, Castelnavia, Dicraea, Lophogyne, Podostemon, Rhyncholacis, Zeylanidium* and at the base of the emergences on the inflorescence axis of *Mourera fluviatilis* Aubl. **Stomata** are unknown, and the **epidermis,** which is seldom well differentiated, as well as the subjacent cells contain chlorophyll. The outer wall of each cell of the mature epidermis in *Podostemon atrichus* Chod. et Visch. is, according to Chodat and Vischer (400), provided with a circular or ellipsoidal disk of cutin, which appears to have the form of a ring because it is particularly thick at the periphery. The rest of the outer wall of the epidermal cells is composed of cellulose. Chodat and Vischer suggest that these cells serve for the rapid absorption of salts and gases dissolved in the water in which this species grows. **Secretory cells** and **cavities** are known to occur in certain genera. **Fungal hyphae** have been reported by Steude (2198) to occur in the secretory cavities of *Mourera aspera* (Bong.) Tul. (See also under 'Thallus' on p. 1103.)

Since the time when Solereder summarized the information concerning its anatomical features, the family has been investigated especially by Matthiesen (1456), Went (2410), and Engler (635), whilst others have made special studies of a single or a few species. The present description is based mainly on these accounts.

THALLUS

The plant body of the Podostemaceae can most conveniently be regarded as a thallus. Engler (635) accepts the view that the fundamental morphological nature of the thallus is a horizontal assimilatory root which, in many species, resembles a rhizome. Its root-like nature is indicated by the possession of a somewhat abnormal **root-cap.** Typically, e.g. in *Mniopsis saldanhana* Warm., the root is dorsiventrally compressed, the ventral surface being flat and the dorsal convex. A root of this kind contains a central **vascular system** including 2 xylem groups, the latter containing but few vessels. According to Engler the xylem is sometimes completely absent, in which case the vascular tissue consists wholly of phloem, but the vascular strand is supported by collenchyma especially on the dorsal side. The remainder of the root consists of large, amyliferous cells. In *Mniopsis saldanhana* and similar species the roots are attached to the substratum by hair-like organs. The roots possess considerable powers of regeneration, and small pieces of them can survive under stones, &c., during dry periods.

The type of root just described may be regarded as fundamental, but there are several very distinct modifications of it in different members of the family. In species of *Dicraea* some of the roots are of the creeping kind just described but others are free-floating and ribbon-like. The flattened roots exhibit palisade tissue towards the upper surface. In species such as *Zeylanidium olivaceum* (Gardn.) Engl. the root has the form of a flattened thallus, which adheres closely to the substratum. In many species the roots bear organs which are sometimes described as shoots and leaves, but it is often difficult to distinguish between these various morphological categories, especially as the so-called branches of the shoots do not arise from axillary buds.

According to Steude (2198), **floating stems** of *Mourera aspera* (Bong.) Tul. exhibit a **central cylinder** containing a number of vascular bundles in which large **air canals** develop where the vessels collapse. The vessels are at first provided with spiral and annular thickenings. No sieve tubes were observed, but a thin-walled tissue of narrow elements around the vessels might be mistaken for phloem. Numerous scattered bundles devoid of air canals and including poorly developed vessels occur embedded in the cortical tissue of the same species. Steude found starch to be absent from the cortical ground-tissue, although it was abundant in small cells at the boundary between the cortex and central cylinder, and less plentiful in the ground-tissue of the central cylinder itself. Numerous **emergences,** believed to serve for gaseous exchange between the plant and its aqueous environment, occur on the surface of the floating stems, the emergences on the distal part of the stem being provided with hairs. **Submerged stems** of *M. aspera* were found by Steude to differ in certain respects from those which float. Emergences were absent, and the epidermis was covered with true unicellular **hairs** which were sufficiently numerous on the upper surface to be visible to the naked eye. The vascular bundles in the cortex were seen to be sheathed by collenchyma except in the basal part of the stem, where the collenchyma was replaced by sclerenchyma. The ground-tissue of the central cylinder in the submerged stems consists of narrow, elongated, lignified cells with pitted walls, contrasting strongly with the unlignified xylem composed of parenchymatous cells and a few, small, central vessels. A yellowish, milky fluid is exuded when fresh material of *M. aspera* is broken. This comes from **secretory canals** and cavities in the thallus. **Fungal hyphae** were also seen in the secretory cavities.

Since very little recent information concerning the anatomy of *Hydrobryum* has been recorded in the literature, the following facts from Imamura's (1118) paper on *H. japonicum* Imamura are worth repeating. The plant has a thalloid root which spreads over the surface of the substratum. It possesses a **root-cap** consisting of collenchyma. The cortical cells contain starch. The **vascular system** is in the form of a network in the root (thallus). It consists of elongated cells with abundant contents. The elongated cells of the ventral epidermis serve to attach the thallus to the substratum. **Anthocyan** is produced in the epidermis of plants cultivated in filtered water in the sun, so that the thallus is similar in colour to the substratum.

A cauline bundle accompanied by leaf-traces occurs, according to Engler (635), in *Apinagia* (*Ligea*) *glaziovii* Warm. and *A. riedelii* (Bong.) Tul. A canal occurs in the centre of the cauline bundle in the first of these species and in the basal parts of the leaf-traces in the second. A form of secondary thickening through tangential cell divisions has been reported by Matthiesen (1456) in the basal part of the stem of *Weddellina squamulosa* Tul.

A milky secretion from *Mourera aspera* is mentioned above. **Secretory elements** are also known to occur in *Podostemon* and other genera. Engler (635) recognized 2 types. (i) A small type, occurring immediately below the surface of the thallus (sometimes in the floral organs), and filled with an unidentified material, in species of *Mourera*, *Oenone*, and *Rhyncholacis*. (ii) A larger type, filled with thread-like colourless contents in material preserved in alcohol, in species of *Castelnavia*, *Marathrum*, *Rhyncholacis*, *Weddellina*. Red deposits in the epidermal and other cells of the capsule wall, as well as in certain other parts of the plant, recorded in *Castelnavia lindmaniana* Warm. Cubical **crystals** of calcium oxalate are stated by Engler (635) to have been found in *Mourera fluviatilis* Aubl. and *Oenone multibranchiata* Matth. 'Leucoplasts' are stated in the literature to be common in the leaves except in *Lawia*, *Tristicha*, and *Weddellina*.

Silicious bodies are secreted in large numbers in many species, especially in the peripheral tissues and even in the hairs of all parts of the plant. They are, however, absent from free-floating leaves. They enable the plants to withstand mechanical damage and periods of desiccation. *Podostemon galvonis* Warm. is so thickly coated with these bodies that the dried and fresh plants look very much alike. *P. subulatus* Gardn., on the other hand, in which silica bodies do not occur, shrinks very considerably when dried.

TAXONOMIC NOTES

The taxonomic position of the family has been much disputed, and very little reliable information concerning its affinities is available. For further details see Engler's (635) account. Willis (2436) has followed up his earlier work on the Podostemaceae by discussing the methods by which they may have been evolved. In his view they must have arisen by a series of rather profound modifications rather than by a gradual series of smaller changes in response to environmental conditions.

GENERA DESCRIBED

Apinagia, Castelnavia, Dicraea, Hydrobryum, Lawia, Lophogyne, Marathrum, Mniopsis, Mourera, Oenone, Podostemon, Rhyncholacis, Tristicha, Weddellina, Zeylanidium.

LITERATURE

On General Anatomy

Chodat and Vischer **400**, Engler **635**, Imamura **1118**, Matthiesen **1456**, Steude **2198**, Went **2410**, **2411**, Willis **2436**.

219. HYDROSTACHYACEAE

Very little is known concerning the anatomy of the small family Hydrostachyaceae, consisting of submerged aquatic plants with tuberous stems, which occur in Madagascar and South Africa. Schloss (2034) states that *Hydrostachys natalensis* Wedd. has leaves that bear pointed **emergences** whose mode of development he has described. Schloss also states that the structure of all of the organs of the same species is remarkably homogeneous. According to Solereder, a ring of isolated **vascular bundles,** accompanied by medullary and cortical strands, occurs in the inflorescence axis of *H. imbricata* Juss. Solereder has also recorded the occurrence of clustered **crystals** of calcium oxalate.

GENUS DESCRIBED

Hydrostachys.

LITERATURE

On General Anatomy

Schloss **2034**.

220. NEPENTHACEAE

(Fig. 266 on p. 1106; Fig. 267 on p. 1108; Fig. 268 on p. 1110)

Summary

This family consists of the well-known 'Pitcher Plants' belonging to the genus *Nepenthes*, which are frequently cultivated in glasshouses on account of their interesting pitcher-like leaves in which small animal organisms are trapped and subsequently digested by special glands. In the wild, these plants occur as prostrate, erect, or scandent undershrubs in Madagascar and the Malayan region. The leaf consists of a basal 'lamina' attached to the stem by a short 'petiole', a cylindrical portion resembling a tendril attached to the apex of the 'lamina' serving to connect this with a terminal 'pitcher' provided with a lid. It is not within the scope of this book to deal with the various morphological interpretations of the leaf and pitcher of *Nepenthes* which have been advanced by different authors (Arber 32, Harms 903, Kuhl 1293, Lloyd 1383, and Stern 2197). The terms 'lamina', 'petiole', 'pitcher', and 'tendril' are used here in a purely descriptive sense. The plants are provided with various kinds of glands, of which 4 main types, known respectively as **hydathodes, honey-glands, digestive glands,** and **marginal glands,** are recognized. These are described more fully below. **Spiral elements,** to which a water-storing function has been attributed, are a very characteristic feature. They occur in the parenchymatous tissues of both stem and leaf. The occurrence of **cortical** and **medullary vascular bundles** in the stem of certain species is also noteworthy.

Leaf

For general morphology see 'Summary'.

Trichomes and Glands

Non-glandular trichomes very infrequent in some species, but much more numerous in others. Simple, unicellular **hairs** rare, uniseriate types consisting of 2–8 cells more numerous. Clustered rosette and dendroid types also occur (Fig. 266 c–f). **Hydathodes** (Fig. 266 a–b) present on the lamina, the exterior of the pitchers, and on the stems; consisting of peltate glands, usually sunk in depressions, but in some species level with or even raised above the epidermis. Peltate glands each with a foot of 1 to several cells and a stellate or circular head of 4–16 cells. Hydathodes are believed to secrete water in normal circumstances, but Macfarlane (1410) has suggested that they absorb water as well. Their mode of development has been described by Stern (2197). Multicellular, **nectar-** or **honey-glands** (Fig. 267 g), usually sunk in depressions, widely distributed on leaves and stems, those on the stems of *Nepenthes mirabilis* (Lour.) Druce said by Harms (903) to be provided with 3 layers of secretory tissue, the outermost layer consisting of columnar cells. Each gland is situated at the end of a vascular bundle. The nectar is secreted through the orifice of a narrow canal. Nectar-glands on the stem of *N. bicalcarata* Hook. f. described by Harms as specially large and branched; when present on the leaf appearing as small, yellowish-green papillae with a central aperture, less numerous on the upper than on the lower surface; their frequency, distribution, and the extent to which sunken in the tissues vary from species to species. Glands of *N. lowii* Hook. f. large and deeply embedded; said to be absent from *N. ampullaria* Jack. Honey-glands, like the digestive glands, originate wholly from the epidermal layer.

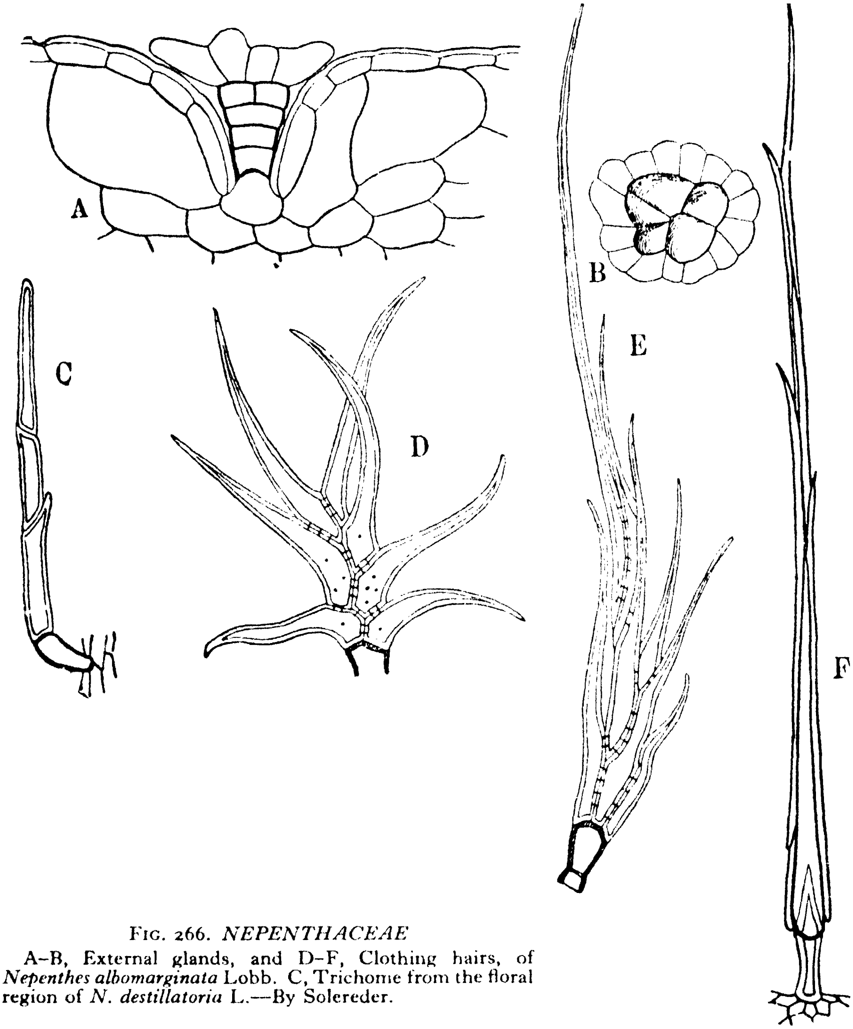


FIG. 266. *NEPENTHACEAE*
A–B, External glands, and D–F, Clothing hairs, of *Nepenthes albomarginata* Lobb. C, Trichome from the floral region of *N. destillatoria* L.—By Solereder.

Digestive glands (Fig. 267 D–F) present on the inside and particularly at the base of the pitchers, but their distribution varies in different species. Glands uniformly distributed over the shiny surface of the interior of the pitchers in *N. ampullaria*, *N. bicalcarata*, and *N. lowii*; confined to the lower part of the pitcher in *N. alata* Blanco, *N. gracilis* Korth, and *N. khasiana* Hook. f. Digestive glands consist of small, multicellular masses of tissue, the outermost layer of cells being columnar. Each gland is typically situated in a depression at the termination of a vascular bundle, and partly enclosed by a roof-like extension of the epidermis at the margin of the gland. The extent to which the glands are covered by the epidermis varies very considerably. The small glands at the upper end of the mature pitcher of *N. lowii* are completely covered with downwardly projecting, cutinized epidermal flaps. Gradual transitions can be traced from the glands of this type to those at the bases of the pitchers which have the form of large quadrangular or polygonal masses of secretory tissue separated from each other by ridges of thick-walled epidermal cells. According to Stern (2197) the cells of the outermost layer of the digestive glands have cutinized radial walls, whilst the radial and to a lesser extent the tangential walls of the cells below are also cutinized. Some investigators have stated that there are pores in the cuticle, but this was not definitely confirmed by Stern. The epidermal cells bordering on the glands were found to give a positive reaction for lignin when treated with phloroglucin.

Marginal glands. These consist of large, ovate or cylindrical masses of secretory tissue embedded in deep cavities on the inside of the 'collar' of the pitcher. They communicate with the exterior through canals, and their bases are at the terminations of vascular bundles. The outermost layer of the gland is composed of columnar cells. Most of the remainder of the gland is parenchymatous, but the elements at the centre are somewhat prosenchymatous, and the peripheral layer between the gland and the surrounding leaf tissue is composed of flattened cells, strongly cutinized on the radial and to a lesser extent on the tangential walls. According to Stern (2197), whereas the whole of the secretory tissue in the digestive glands originates from the epidermis, in the marginal glands only the layer of columnar cells arises from the epidermis.

'LAMINA' AND 'PETIOLE'

Lamina distinctly dorsiventral in some species, but palisade tissue not very well defined in others. **Stomata** numerous, but confined to the lower surface; those of *N. ratcliffiana* Veitch ex Masters and '*N. hainaniana*' observed to be ranunculaceous. An aqueous **hypoderm** usually present, especially towards the upper surface, where it may consist of 1–3 layers of cells. **Mesophyll** including up to 5 layers of palisade cells, and cells with spiral bands of cellulose thickening (Fig. 267 A–B). **Midrib** with similar vascular structure to that of the petiole. Leaf base or **'petiole'** (Fig. 268 A), in transverse sections taken just below the lamina of '*N. hainaniana*' and *N. ratcliffiana*, exhibiting the following vascular structure in material examined at Kew. Vascular system in both species appearing as an adaxially flattened cylinder of widely spaced, collateral, vascular bundles connected by a zone of sclerosed cells. Larger vascular bundles in the adaxial part of the cylinder for the most part normally orientated, with xylem towards the adaxial surface, but smaller vascular strands in the same region exhibiting partial to complete inverse orientation. Vascular bundles in the abaxial part of the cylinder in '*N. hainaniana*' mostly smaller than those towards the adaxial surface, but very variously orientated; those in the corresponding position in *N. ratcliffiana* mostly exhibiting normal orientation, but a few somewhat oblique.

One large medullary bundle with adaxial xylem is enclosed within the main vascular cylinder in '*N. hainaniana*', and 2 in the corresponding position in *N. ratcliffiana*; numerous small additional bundles in the wings in both species.

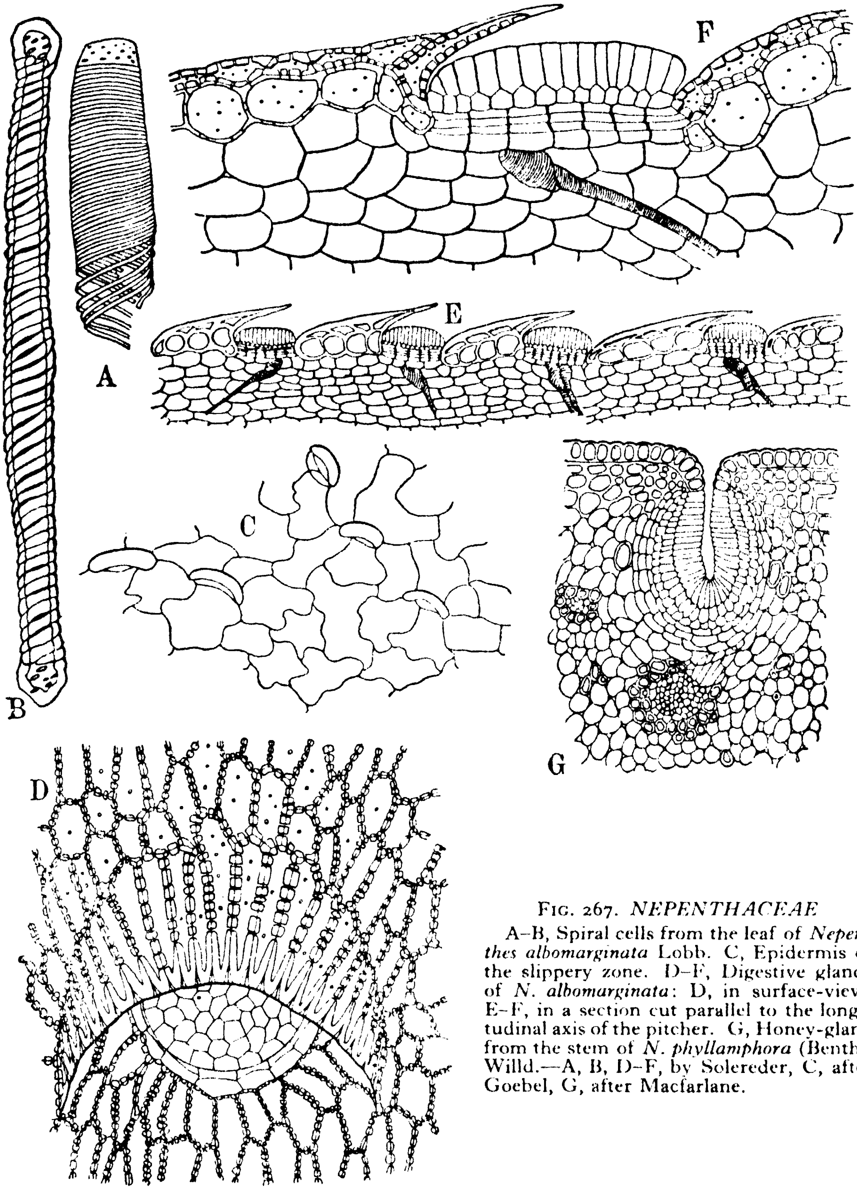


FIG. 267. *NEPENTHACEAE*
A–B, Spiral cells from the leaf of *Nepenthes albomarginata* Lobb. C, Epidermis of the slippery zone. D–F, Digestive glands of *N. albomarginata*: D, in surface-view; E–F, in a section cut parallel to the longitudinal axis of the pitcher. G, Honey-gland from the stem of *N. phyllamphora* (Benth.) Willd.—A, B, D–F, by Solereder, C, after Goebel, G, after Macfarlane.

All petiolar vascular bundles supported externally by fibres. **Secretory elements.** Cells of the mesophyll packed with unidentified but probably tanniniferous material in '*N. hainaniana*'; similar deposits much less abundant in *N. ratcliffiana*. Occasional cluster **crystals** present.

'TENDRIL' (Fig. 268 C)

Transverse sections, according to Macfarlane (1410), exhibit vascular bundles united by sclerenchyma to form a ring. Bundles on the adaxial side of the tendril sometimes inverted, the xylem groups being internal and the phloem external, the vascular structure then approximating to that of a stem. Medullary bundles well developed. Similar structure was observed in tendrils of '*N. hainaniana*' and *N. ratcliffiana* Veitch ex Masters examined at Kew. Some of the smaller adaxial strands of the main ring consist only of phloem in *N. ratcliffiana*; larger bundles in the same region collateral but showing partial or complete inverse orientation. Nearly all of the adaxial bundles of '*N. hainaniana*' show complete or almost complete inverse orientation. Two normally orientated medullary bundles noted in *N. ratcliffiana*, but none seen in '*N. hainaniana*', although one large abaxial bundle in the last species was somewhat within the main circle.

PITCHER

Inner surface of the pitcher usually consisting of a **slippery zone** towards the mouth and a **glandular zone** towards the base, but the proportion of the pitcher occupied by these 2 zones varies considerably in different species. Sometimes the whole internal surface is uniform, glands being present on all parts. Surface of the slippery zone devoid of glands, but covered with a granular layer of wax. Numerous, transversely placed, **ledge-like cells,** densely covering and slightly raised above the epidermal surface, are said to assist in preventing the escape of animal organisms which fall down the slippery surface of the interior of the pitcher. Macfarlane (1410), whose views have been confirmed by Lloyd (1383), interprets these papilla-like structures as modified stomata, and states that those in immature pitchers are more like ordinary stomata. **Nectar-glands** (see p. 1105) present on the outer surface of the pitcher and both surfaces of the lid. **Digestive glands** occur at the base of or all over the inner surface of the pitcher according to the species. The corrugated surface of the mouth of the pitcher consists of radial rows of cuticlarized epidermal cells. **Marginal glands** occur in this region. **Epidermis** composed of thick-walled cells. **Stomata** present on the outer surface of the pitcher as well as on both surfaces of the lid. **Spirally thickened cells** occur embedded in the wall of the pitcher. Walls of the pitcher supplied by numerous **vascular bundles** with very well-developed phloem, the vascular strands, or at least the larger ones, being sheathed with fibres.

AXIS

STEM (Fig. 268 D)

Primary **cortex** differentiated into an outer zone of fibrous cells (Fig. 268 D, *a*) and an inner zone of much larger cells (Fig. 268 D, *b*); elements with spiral bands of cellulose thickening embedded in both of the cortical zones. **Cork** arising in the pericyclic region, all of the outer tissues being cast off after its development. **Endodermis** clearly defined. **Pericycle** consisting largely of spirally thickened cells, the lumina of the spiral cells becoming practically filled up by the thickened walls when sufficiently old. **Vascular system** appearing in transverse sections as a circle of 20–30 closely packed vascular bundles, separated only by narrow rays and thus resembling a continuous cylinder. **Xylem** including vessels 70–90 μ in diameter, but occasionally much larger, with simple perforations; fibres with bordered pits. **Pith** mostly composed of large cells (Fig. 268 D, m_2). Peripheral part more or less demarcated as a distinct ring (Fig. 268 D, m_1), composed of prosenchymatous cells with thin transverse partitions accompanied by shorter cylindrical cells. Scattered spiral cells present in the pith. **Medullary bundles** occur in some species; 5–8 recorded by Macfarlane (1410) in *N. hookeriana* Lindl. One medullary bundle with central phloem noted at Kew in *N. ratcliffiana* Veitch ex Masters; none seen in '*N. hainaniana*'. **Cortical bundles**, embedded in the fibrous zone, occur in young stems. Occasional clustered **crystals** observed. Sphaerocrystalline material also reported to occur in specimens preserved in alcohol. **Secretory elements.** Abundant, unidentified but probably tanniniferous contents present in all the cells situated between

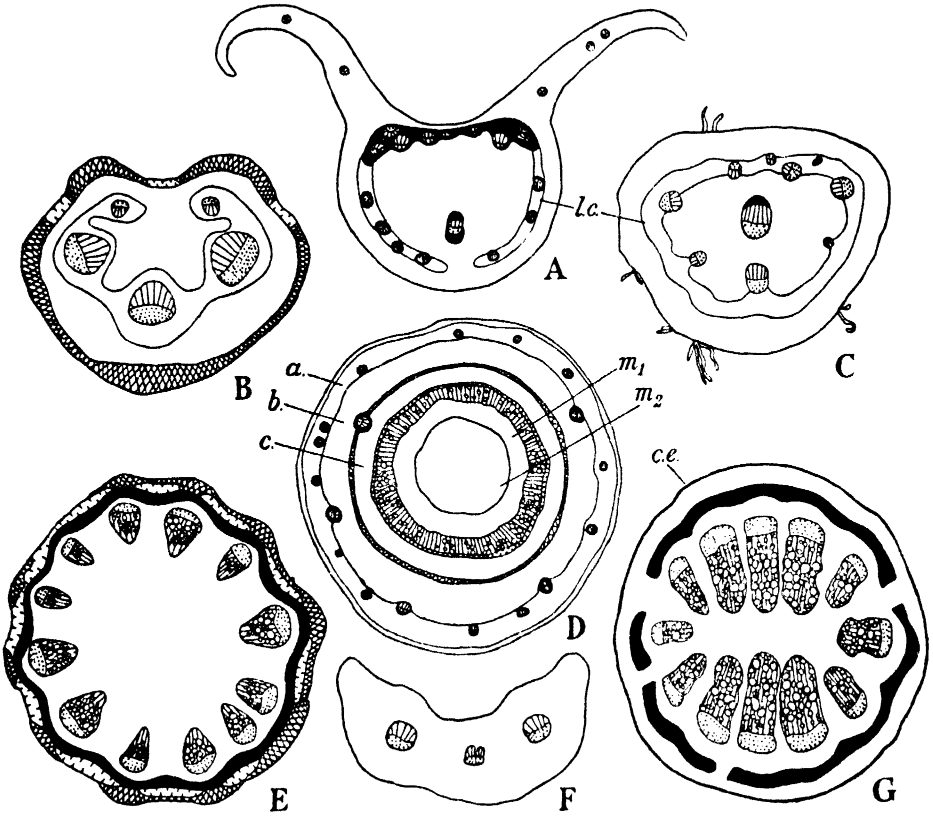


FIG. 268. *NEPENTHACEAE*, A and C–D; *ARISTOLOCHIACEAE*, B and E–G

A, *Nepenthes 'hainanensis'*. Petiole × 11. B, *Asarum canadense* Linn. Petiole × 23. C, *Nepenthes ratcliffiana* Veitch ex Masters. Tendril × 24. D, *N. 'hainanensis'*. Stem × 5. E, *Asarum canadense* Linn. Stem × 16. F, *Aristolochia clematitis* Linn. Petiole × 13. G, *A. sipho* L'Hérit. Stem × 9.

a. Zone of fibrous cells with thick walls. *b.* Zone of large cells with thin walls. *c.* Spiral and tanniniferous cells. *c.e.* Cutinized epidermis. *l.c.* Lignified cells. m_1. Zone of prosenchymatous cells. m_2. Zone of large cells with thin walls.

those with spiral thickenings in the pericyclic region (see under 'Pericycle', p. 1109). Cells with mucilaginous or tanniniferous contents also noted in the cortex and pith.

RHIZOME

Numerous albuminous bodies recorded in the parenchyma of the cortex and rays of *N. gymnamphora* Nees.

ROOT

The following facts have been recorded by Harms (903). Root **hairs** very numerous. **Cortex** composed of dark-brown tissue. Primary **vascular structure** tetrarch to hexarch.

TAXONOMIC NOTES

The affinities of *Nepenthes* have been much discussed. It is commonly held that *Nepenthes* and *Sarracenia* (Family Sarraceniaceae) are related. It has also been claimed that there are affinities between *Nepenthes* and the Droseraceae, but these are less well established.

GENUS DESCRIBED

Nepenthes.*

* Represented in the Kew slide collection.

LITERATURE

On General Anatomy

Arber 32, Harms 903, Kuhl 1293, Lloyd 1383, Macfarlane 1410, Stern 2197.

221. RAFFLESIACEAE

SUMMARY

A family of tropical and sub-tropical herbs which are parasitic on the roots, stems, and branches of various woody plants. The Rafflesiaceae sometimes possess greatly reduced leaves, but the vegetative body consists mainly of thalloid tissue which becomes intermingled with that of the host plant. For further details see under 'Thallus and Flowering Axis'. The plants are believed to be devoid of chlorophyll, whilst somewhat abnormal **stomata** have been recorded in a few species. A **vascular system** exists only in those members of the family which have a fairly massive thallus. The flowering axis is generally initiated endogenously from balls of parenchymatous tissue, often referred to as 'floral-cushions', within the tissues of the host. The flower-bearing axis thus has to perforate the host tissues before reaching the exterior. The inflorescence axis of *Pilostyles ulei* Solms-Laubach is exceptional in arising exogenously from the 'floral-cushion'.

SCALE LEAVES

Hairs sometimes present, but their structure is not well known; most of those described occur only on the floral organs, e.g. glandular trichomes on the bracts of *Cytinus*. Scale leaves of *Rafflesia patma* Blume described by Hunziker (1112) as having an outer epidermis of axially elongated, lamelliform cells, the homogeneous mesophyll being composed of cells with wide lumina.

Stomata recorded on the outer surface in *Pilostyles ulei* Solms-Laubach, structures resembling mucilage pores or nectaries also being present in the same region. Functionless stomata reported to occur on the lower surface of the basal leaves of *Cytinus hypocistis* Linn., whilst structures believed to be reduced stomata have been described by Cammerloher (331) in *Brugmansia* and *Rafflesia.*

THALLUS AND FLOWERING AXIS

The thallus of *Pilostyles*, *Rafflesia*, and *Rhizanthes* (*Brugmansia*) consists of simple or branched rows of cells resembling fungal hyphae which penetrate the host tissues. The parasite can be detected in the tissues of the host by its very large nuclei. In some species the filamentous thallus is confined to the phloem and other tissues of the host which are rich in food reserves. In *Rafflesia manillana* Tesch., according to Brown (294), on the other hand, the filaments of the thallus penetrate the xylem, medullary rays, cambium, phloem, and sclerenchyma of the host, and apparently grow and multiply in all of these tissues, except perhaps the sclerenchyma. Brown also says that the filaments of thallus have but little power of conduction, and probably do but slight damage to the tissues of the host. In the same species the thallus tissue also occurs in the form of plates or irregular masses embedded in the tissues of the host. Layers of cork-like cells, which are frequently produced in the tissues of the host around the parasite, may cut off the supply of food to the latter and so cause its death. A somewhat similar reaction on the part of the host to parasitic invasion by another species of *Rafflesia* has also been described by Cartellieri (344), but here some of the filaments of thallus generally survive and subsequently proliferate. In *R. manillana*, Brown also found that some of the xylem elements and sieve tubes become connected with the corresponding elements of the host, whilst Cartellieri has stated that, in species which he examined, some of the absorbing threads of the parasite penetrate the vessels of the host. Harms (900), recalling an earlier account by Goebel, has pointed out how, in *Pilostyles haussknechtii* Boissier, the threads of thallus pass through the parenchyma of the cortex and pith of the species of *Astragalus* on which they grow, extend to the apical growing-point, and send out branches into the leaf rudiments. The thallus of *Cytinus hypocistis* Linn., which occurs on the roots of *Cistus* spp., has the form of a massive but invaginated cylinder, situated between the cambium and xylem of the host.

The vascular system is very much reduced. When the thallus is filamentous, conducting elements are generally absent, but definite vascular strands are known to occur when the thallus is more massive. Centric bundles, 'which end in the general region of the cambium of the root', have been recorded by Brown (294) in *Rafflesia manillana*. Tracheids occur in *Pilostyles ulei* Solms-Laubach, and vascular strands in the thallus of *Cytinus hypocistis*, *Pilostyles aethiopica* Welw., and *P. thurberi* A. Gray. Vascular bundles are generally present in the 'floral cushion' from which the flowering axis arises, as well as in the flower-bearing axis itself. A circle of about 20 bundles has been recorded in the 'floral cushion' of *Rafflesia rochussenii* Teijm. et Binn. Hunziker (1112) found that, in *R. patma* Blume, the conducting elements are short-membered, broad, dense, spirally thickened tracheids without contents. The older elements are mostly devoid of transverse walls, and thus tend to have the structure of vessels. The narrow, elongated, phloem elements in the same species are provided with intensely coloured cytoplasm and nuclei.

TAXONOMIC NOTES

The numerous taxonomic affinities suggested for this family have been summarized by Harms (900). Owing to the very specialized structure of the plants it is difficult, on anatomical grounds, to draw conclusions concerning the relationships of the plants.

GENERA DESCRIBED

Brugmansia, Cytinus, Pilostyles, Rafflesia, Rhizanthes.

LITERATURE

On General Anatomy

Brown **294**, Cammerloher **331**, Cartellieri **344**, Harms **900**, Hunziker **1112**.

222. HYDNORACEAE

Members of this family are parasitic plants from tropical and sub-tropical regions, very much like those belonging to the closely related Rafflesiaceae, but differing in the absence of scale leaves. The plant first appears as a tuberous structure attached to the host. A branched subterranean system of shoots, sometimes termed 'rhizoid-shoots' or 'rhizoids', subsequently grows out from the initial tuber and bears the subsessile flowers. In the absence of recent work on the anatomy of the family, the following particulars have been taken from Solereder's account. Additional details may be found in Harms's (901) description. Absorption of food from the host plant takes place through the 'rhizoids', which are angular or circular in transverse section in different species. A thick layer of cork cells covers the external surface of the 'rhizoids', and serves as a covering to a parenchymatous cylinder containing the vascular bundles. The vascular bundles are variously arranged in different species, and may be in one or more rings and exhibit normal or inverse orientation. Sieve tubes have been definitely seen only in the phloem of *Prosopanche*. Simple perforations have been recorded in the vessels of the same genus. The innermost portion of the 'rhizoid' consists of a strand of elongated pith cells which are fibrous in *Prosopanche*, but prismatic in *Hydnora*. The cells of the parenchymatous ground-tissue contain brown, tanniniferous, mucilaginous contents, starch, and sometimes tetragonal crystals. Strands of loosely connected mucilage cells have also been recorded in the 'rhizoids' and peduncle of *Prosopanche burmeristeri* de Bary. These strands, in some instances, become converted to mucilage canals or receptacles, owing to the breakdown of the cells.

GENERA DESCRIBED

Hydnora, Prosopanche.

LITERATURE

On General Anatomy

Harms **901**.

223. ARISTOLOCHIACEAE

(FIG. 237 on p. 1010; FIG. 264 on p. 1088; FIG. 268 on p. 1110; FIG. 269 on p. 1116)

SUMMARY

(i) GENERAL

A family from tropical and temperate regions, consisting mostly of woody plants of which many are climbers, but including some herbaceous species. The most conspicuous anatomical feature of the axis is that the primary **medullary rays** are broad, so that the **vascular bundles** are widely separated from one another. In addition, the xylem groups become fissured in old stems, owing to the development of broad secondary medullary rays. The resulting vascular structure of the stem is generally known as the '*Aristolochia* type'. **Anomalous structure** has been reported to occur in *A. triangularis* Cham., but this appears to represent only an extreme form of the kind of vascular structure that is usual in the stems of this family. In stems showing this anomaly the pith and primary rays are more than usually dilated, whilst secondary xylem is formed between the portions into which the normal xylem becomes separated. **Hairs** are mostly simple and uniseriate, but sometimes possess hooked terminal cells. The ranunculaceous **stomata** are usually confined to the lower surface of the leaf, or, more rarely, occur on both sides. The upper **epidermis** of the leaf and/or adjacent palisade tissue often contains groups of silicified cells. **Crystals,** which are fairly frequent, are mostly in the form of small prisms, needles, or clusters. **Secretory cells,** with contents of a somewhat varied but frequently oily nature, occur in the parenchymatous tissues of both stem and leaf. Their mode of development has been described by Lehmann (1343).

(ii) WOOD

Vessels large and tending to be solitary in the twining species, small in *Apama*, perforations simple, intervascular pitting alternate and small to large, pits to ray cells large and elongated when present, members of medium length to moderately short. **Parenchyma** variable, as uniseriate apotracheal lines or scanty paratracheal. **Rays** in the twining species limited to the interfascicular type and both wide and very high; normal rays present in *Apama*, small, heterogeneous and containing oil or mucilage cells. **Fibres** with bordered pits, of medium length.

LEAF

Generally dorsiventral, but mesophyll sometimes consisting of homogeneous, muriform parenchyma; rarely isobilateral, with palisade tissue towards both surfaces, e.g. in *Aristolochia claussenii* Duch. and *A. maurorum* Linn. **Hairs** mostly in the form of simple, uniseriate trichomes, but exhibiting differences in the thickness of the walls and in the number and length of the component cells. Some of the hairs in species of *Apama*, *Aristolochia*, and *Thottea* each have a dome-shaped pedestal, a short neck cell, and a hooked terminal cell with a silicified tip (Fig. 269 K). The terminal cells of some of the hairs in *Saruma* contain crystal sand. Typical glandular hairs absent, but hairs with basal secretory cells recorded (Fig. 269 A). **Cuticle** frequently granular, but not known to be striated. **Epidermis** often papillose on the upper or lower surface in species of *Aristolochia*, *Asarum*, *Thottea*. Groups of **silicified cells** (Fig. 269 C–J) occur in the upper epidermis and/or adjacent palisade tissue in many species of *Aristolochia* as well as in *Apama*, *Holostylis*, and *Thottea*. Silicified cells generally visible with a lens as white or lustrous elevations on the upper surface of the leaf.

Hypoderm rarely developed; recorded towards the upper surface of the leaf in a few species of *Aristolochia*, and a similar layer composed of thick-walled cells in *Thottea grandiflora* Rottb. **Stomata** usually confined to the lower surface, but recorded on both sides in some species of *Aristolochia*, *Asarum*, *Holostylis*; ranunculaceous. **Mesophyll** generally including a single layer of palisade cells. These are low, broad, and lobed in *Aristolochia serpentaria* Linn. according to Holm (1020). Palisade cells also short in *Asarum canadense* Linn. (Holm 1055). Isolated or small groups of palisade cells horizontally divided by thin transverse walls, e.g. in *Aristolochia sipho* L'Hérit. Vascular bundles of the **veins** always embedded in the mesophyll; accompanied by sclerenchyma in some species or by none in others. Those of *A. bracteata* Retz. said by Sabnis (1977) to be provided with green sheaths.

Petiole (Fig. 268 B, F) described by Schmidt (2039) as showing a crescentic or cylindrical vascular system, dissected into separate strands by broad strips of parenchyma. Transverse sections through the distal end of the petiole of *Aristolochia clematitis* Linn. (Fig. 268 F) exhibit an arc of a few widely spaced vascular bundles, and in *Asarum canadense* (Fig. 268 B) a more or less complete cylinder of widely spaced bundles in material examined at Kew.

Secretory cells (Fig. 269 B) present in all investigated members of the family, usually occurring not only in the leaf but also in the parenchymatous tissues of the axis, as well as in the flowers, fruits, and seeds. According to Solereder they are absent from the lamina of the leaf of *Aristolochia serpentaria*, *A. sipho*, and a few other closely related species, but occur in other parts of the plant in these species. Secretory cells stated by Schmidt (2039) to occur in the epidermis on both surfaces of the leaf in *A. brasiliensis* Mart. et Zucc., *A. hians* Willd., *A. maurorum*, &c., but confined to the lower epidermis in *A. baetica* Linn., *A. clematitis*, and *A. tagula* Cham. Secretory cells spherical or ellipsoidal, more rarely branched, e.g. in *A. nervosa* Duch.; walls usually suberized; contents consisting of yellowish, whitish, or occasionally reddish material, but not of uniform chemical composition; colour changed to indigo blue on treatment with eau de Javelle in *A. lindeniana* Duch. var. *plagiophylla* Griseb. The oil in the secretory cells of *Asarum europaeum* Linn., *Aristolochia brasiliensis*, and *A. clematitis* is enclosed by a membrane according to Schmidt (2039). The chemical nature of the material secreted in various members of the family has been described in more detail by the same author. The distribution of the secretory cells is said by Solereder to be valuable for the identification of species, but this matter needs reinvestigation, as the position of the secretory cells may alter during the development of the leaf. Cells with tanniniferous contents recorded in the region of the veins in some species, e.g. in *Aristolochia galeottii* Duch. **Crystals** fairly frequent, occurring in the form of small prisms, needles, and clusters.

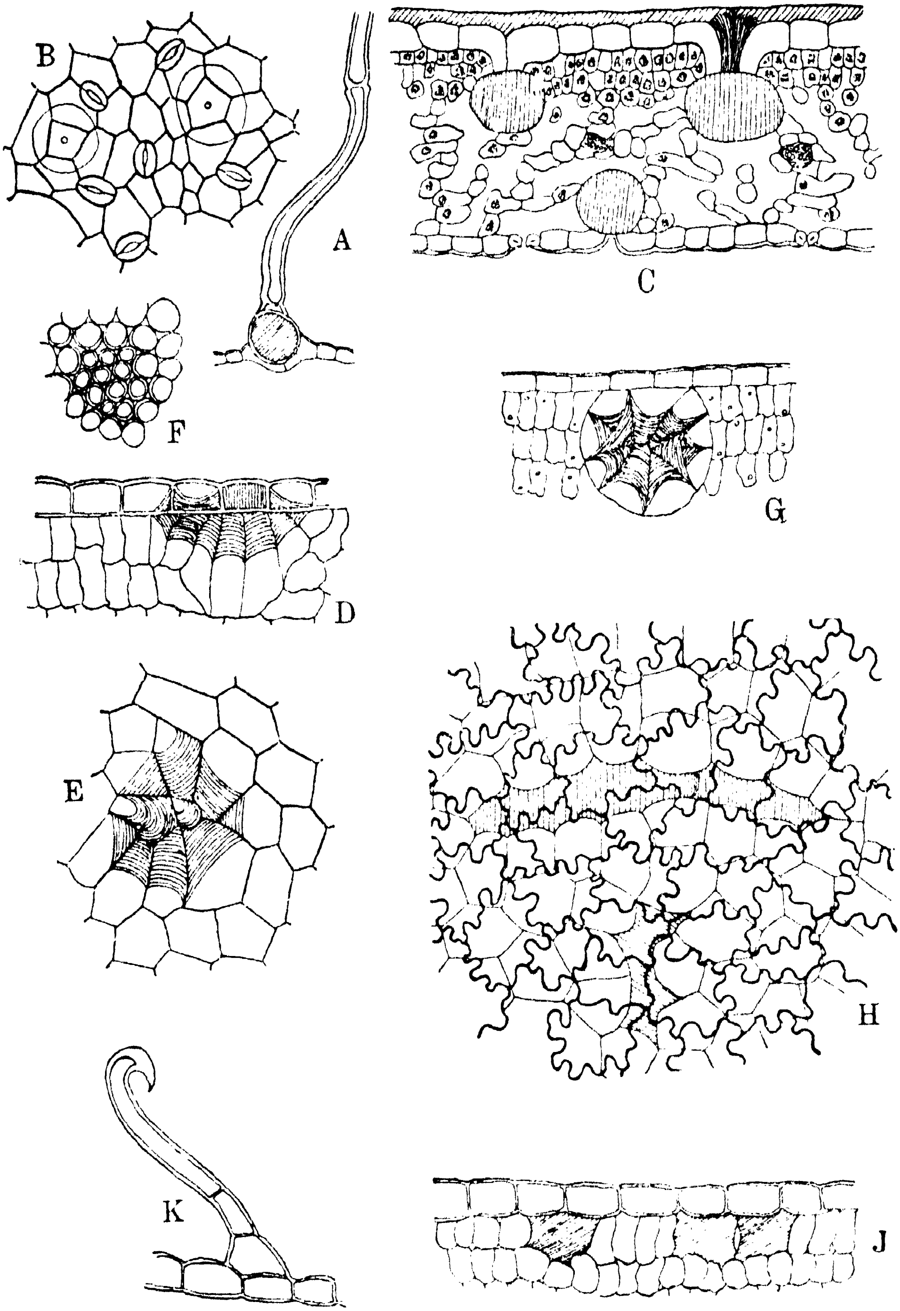


Fig. 269. *ARISTOLOCHIACEAE*

A, Hair of *Aristolochia sericea* Benth. with a basal secretory cell. B, Secretory cells in the lower epidermis of the leaf of *A. brachyura* Duch. C, Transverse section of leaf of *A. trichotoma* Griseb. D–F, Group of silicified cells from the leaf of *A. tomentosa* Sims.: D, in section; E, silicified group of epidermal cells; F, group of subjacent palisade cells in surface-view. G, Group of silicified cells in the mesophyll of *A. acutifolia* Duch. H–J, Siliceous cells in the leaf of *Thottea dependens* Klotzsch: H, in surface-view; J, in section K, Bracket-hair of *Aristolochia tomentosa* Sims.—By Solereder.

AXIS

STEM (Fig. 268 E, G)

Frequently angled when young. Chiefly remarkable for the broad, primary **medullary rays** between the large, collateral, **vascular bundles** arranged in a ring. Rays especially conspicuous in woody species (see under 'Wood', below). The vascular bundles in old stems become dichotomously fissured owing to the development of broad secondary rays, thus producing the kind of structure known as the '*Aristolochia* type' (Fig. 237 E). **Cork** originating in the sub-epidermal region in *Aristolochia*; consisting in the same genus of alternate layers of thin-walled cubical cells and cells with cellulose walls. Outer layers of the cortex becoming suberized, and tending to peel off in *Asarum europaeum* Linn. Primary **cortex** sometimes containing stone cells. Collenchyma well developed at the nodes in *A. serpentaria* Linn. according to Holm (1020). **Endodermis** conspicuous in the same species according to Holm (1020). This character also noted at Kew in young stems of other species of *Aristolochia*. Outer portion of the **pericycle** generally containing a wide, closed ring of sclerenchyma when young, but fibres becoming split up into separate strands in older material as a result of secondary thickening. Large gaps in the ring of pericyclic sclerenchyma, opposite some of the broad medullary rays, noted in old stems of *Aristolochia sipho* L'Hérit. (Fig. 268 G). Pericyclic fibres provided with rather wide lumina and sometimes with thin, transverse septa. Secondary **phloem** occasionally including stone cells, but, according to Solereder, never fibres. Sieve tubes often with wide lumina and the sieve plates with coarse pores. **Xylem** including vessels with simple perforations. **Pith** frequently broad; lignified or unlignified in different species. **Secretory cells** with oily contents usually present (see also under 'Leaf'). **Crystals** variously distributed and often abundant; occurring in the form of small prisms, needles, and clusters.

WOOD (Fig. 264 F–G)

Vessels very large in some of the twining species, e.g. the largest vessels up to 450 μ in *Pararistolochia*, but moderately small (mean tangential diameter 50–100 μ) in *Apama siliquosa* Lam. (syn. *Bragantia wallichii* R. Br.); solitary and in multiples of 2 or 3 cells in the latter (Fig. 264 F), but in the twining species varying from all solitary to solitary large vessels interspersed with groups of small vessels; ring-porous in some species of *Aristolochia* (2261); Solereder reports spiral thickening in the smaller vessels in *A. tomentosa* Sims. Perforations simple. Intervascular pitting alternate, large and often elongated in *Aristolochia* and *Pararistolochia* and small in *Apama*; pits to ray cells elongated and almost scalariform in *Apama*. Mean member length in *Aristolochia* 0·3 mm. (100) and *Apama siliquosa* (syn. *Bragantia wallichii*) 0·6 mm. **Parenchyma** paratracheal in *Apama* and *Aristolochia* and sometimes very sparse in the former, as incomplete sheaths in the latter; Solereder records it as 'in rows accompanying the tracheae' in *Apama* and *Thottea*; apotracheal, as numerous uniseriate bands in *Pararistolochia*. With oil or mucilage cells in *Apama*. **Rays** in the twining species limited to large interfascicular rays that dissect the stem into discrete bundles and which may extend from one internode to another (2261); these rays often contain stone cells (particularly in *Aristolochia*) and druses and, according to Solereder, may be lignified or unlignified. Rays in *Apama* up to 3 cells wide; multiseriate rays less than 1 mm. high; uniseriates very few and low, composed of upright and procumbent cells; about 10 rays per mm.; heterogeneous (Kribs's Type II B), with 1–3 marginal rows of square or upright cells, and with oil or mucilage cells in *Apama*. **Fibres** with bordered pits, the pits very numerous in both radial and tangential walls in *Aristolochia* and *Pararistolochia*, and very large in the former; the pits smaller and mostly in the radial walls in *Apama*. Walls thin except in *Apama*, in which there is a marked difference between early wood and late wood. Solereder notes spiral thickening in *Aristolochia tomentosa*. Mean length about 1·0 mm.

RHIZOME

Sclerenchyma absent from the pericycle, but a well-marked **endodermis** present in *Aristolochia* and *Asarum*. **Xylem** in *Asarum* said by Solereder to be composed wholly of vessels and parenchyma. Centric bundles with central phloem recorded in *Asarum* spp. **Oil cells** also recorded in the same genus, but probably present in the rhizome of other genera as well. For chemical nature of the contents of these cells in *Asarum europaeum* Linn. and other members of the family see Schmidt's (2039) account.

ROOT

Tuberous roots of *Aristolochia fimbriata* Cham. described by Schmidt (2039) as exhibiting a narrow cork composed of very thin-walled cells; an amyliferous, parenchymatous zone of transversely stretched cells; a cambial region separating the parenchyma just mentioned from the pith, the latter being composed of numerous layers of transversely stretched cells; a central strand of conducting elements, with radially arranged groups of lignified tissue extending from it towards the cambial ring, 1 or more rows of fairly large vessels being present in each radial group of lignified tissue; secretory cells embedded in the outer zone of amyliferous cells. Roots of *A. clematitis* Linn. similar in structure. Secretory cells not observed in the roots of certain species, but secondary roots of *Asarum canadense* Linn. provided with 2–3 oil ducts in the phloem and others in the hypodermal region of the cortex according to Holm (1055). Fibres and stone cells noted in the secondary phloem in *Apama siliquosa* Lam. (syn. *Bragantia wallichii* R. Br.) and *Aristolochia indica* Linn.; some of the cells of the medullary rays also becoming sclerosed. Endotrophic mycorrhiza occur in the roots of *Asarum europaeum* Linn. according to Schmidt (2039).

ANOMALOUS STRUCTURE

Recorded only in *Aristolochia triangularis* Cham. after attaining a thickness of 3·5 cm. (Fig. 237 E), where, following enlargement of the pith, the original 8 vascular bundles become converted into fan-shaped segments. Although this structure is described as anomalous, it is not very different from that which occurs in other woody members of the family, apart from the fact that the primary rays and pith are more extensive than usual.

ECONOMIC USES

Some members of the family possess medicinal properties. The most familiar is Serpentary or Virginian Snakeroot, which consists of the dried rhizome of *Aristolochia serpentaria* Linn. and *A. reticulata* Nutt. Both of these species possess tonic properties. The rhizomes, as they appear in commerce, are in pieces about 2 or rather more centimetres long and up to about 3 mm. thick, with the short bases of aerial stems attached to the upper surface, and numerous somewhat curved roots about 10 cm. long and 2 mm. thick attached to the sides and lower surface. Diagnostic microscopical characters for the rhizome are the yellow bundles of xylem, including rather infrequent vessels up to 40 μ in diameter; amyliferous medullary rays 4–8 cells wide; an eccentric, parenchymatous pith, composed of pitted cells; a narrow cork; simple and compound starch grains about 3–15 μ in diameter in the cortex; the absence of crystals, except occasionally in the bases of the aerial stems. Indian Birthwort, which consists of the dried stem and root of *A. indica* Linn., has medicinal properties which somewhat resemble those of Serpentary. Several members of the family have been used in the treatment of snake-bites. The use of members of the Aristolochiaceae for medicinal purposes has persisted from ancient times. The subject is discussed more fully by Schmidt (2039).

TAXONOMIC NOTES

The taxonomic position of the family has been much discussed, and the available suggestions have been summarized by Schmidt (2039). This author rather significantly prefaces his remarks by saying: 'Die Aristolochiaceen sind mit keiner Familie in wirklich engen Zusammenhang zu bringen.' Discussing the subject from the standpoint of a wood anatomist, Tippo (2261, p. 76) says:

> 'Apparently it would be stretching the concept of convergent evolution rather far in attempting to argue that the herbaceous forms coming from the Aristolochiales would be identical in the flower and even in the minutest details of anatomical structure with those woody forms derived from the Hamamelidales. The herbaceous species studied were clearly derivatives of the woody forms. Furthermore, there was no similarity between the anatomy of the Aristolochiales and that of the Urticales. Indeed, the Aristolochiaceae are much more specialized anatomically than are the herbs of the Urticales. The pores are larger, the vessel elements are shorter and some forms are even ring-porous. The rays are very wide in the Aristolochiaceae and so the herbs and vines are divided up into discrete bundles, whereas in the herbaceous forms of the Urticales the rays are narrow and the herbs are of the 'continuous' stele type.'

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Apama, Aristolochia,* Asarum,* Holostylis, Saruma, Thottea.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Apama, Aristolochia, Pararistolochia, (Thottea).

LITERATURE

(i) *On General Anatomy*

Holm **1020**, **1055**, Leemann **1340**, Lehmann **1343**, Rutiewicz **1975**, Sabnis **1977**, Schmidt **2039**.

(ii) *On Wood Structure*

Bailey **100**, Burgerstein **310**, Cozzo **494**, Dadswell and Record **533**, Record **1843**, **1851**, Record and Hess **1886**, Tippo **2261**.

224. PIPERACEAE

(FIG. 270 on p. 1122; FIG. 271 on p. 1124; FIG. 272 on p. 1130)

SUMMARY

(i) GENERAL

A mainly tropical family, mostly herbaceous, but including some shrubby forms. Some species such as *Piper betle* Linn. are lianes climbing by adventitious roots. The most outstanding anatomical character is the nature of the **vascular bundles** in the axis. These are usually scattered like those of the Monocotyledons, but several more or less distinct arrangements occur in the different genera and species. The vessels have simple perforations or scalariform plates with a few bars. **Secretory cells,** with translucent or brown, usually oily contents, occur in both leaf and stem of all investigated members of the family with the exception of the genus *Symbryon*. The secretory cells of the leaf sometimes appear as transparent or opaque dots. The mode of development of the oil cells in *Piper* has been described by Lehmann (1343). Secretory elements are also represented by mucilage canals in the ground-tissue of certain species of *Piper*.

Hairs are never very numerous and mostly uniseriate. Small, spherical, shortly stalked glands, and sometimes deciduous pearl glands, also occur. **Stomata,** nearly always confined to the lower surface, are often surrounded by a rosette of numerous epidermal cells, whilst others are cruciferous. **Hypoderm** is commonly differentiated, and not infrequently consists of a considerable number of layers of cells. **Crystals** are mostly acicular or clustered.

(ii) WOOD

Vessels usually small, solitary and in small multiples, perforations typically simple, but occasional scalariform plates reported, intervascular pitting alternate, minute to moderately large, pits to parenchyma often elongated, vessels seldom in contact with the rays, members of medium length to very short. **Parenchyma** vasicentric, sometimes storied. **Rays** up to 8–45 cells wide and very high, uniseriates absent, composed almost entirely of square and upright cells, occasionally with oil or mucilage cells. **Fibres** with simple pits and occasional septa, moderately to very short.

LEAF

Dorsiventral. **Hairs** rarely forming a dense covering; mostly uniseriate, frequently composed of numerous short cells with wide lumina. Glands, each consisting of a basal cell belonging to the epidermis, a short stalk cell, and an enlarged or sac-like head, recorded in *Peperomia* and *Piper*. Secreted material seldom present in these structures in large quantities. Glistening, deciduous pearl glands (Fig. 270 E), sometimes more than 1 mm. in diameter and each consisting of a single enlarged cell with a narrow base inserted in the epidermis, occur sporadically in *Piper*; usually filled with protein and oil. **Epidermis** and sometimes the hypoderm including silicified cells in certain species of *Piper*; papillose on 1 or both surfaces in a few species of *Peperomia*. Small areas composed of much smaller cells than those of the remainder of the epidermis recorded on the adaxial surface of the leaf in *Piper betle* by Chibber (393); the small cells and those of the subjacent hypoderm being silicified. **Cork excrescences** recorded on the leaf surface in a few species of *Peperomia*. Spots with a silvery sheen on the upper side of the leaf of *Peperomia* are stated to be caused by the development of intercellular spaces in the hypoderm. **Stomata** nearly always confined to the lower surface, but a few noted on the upper side, e.g. by Yuncker and Gray (2501) in *P. leptostachya* Chapm.; often surrounded by a rosette of numerous epidermal cells, but others are cruciferous. A **hypoderm** (Fig. 270 A–B) of 1 to numerous layers of cells present in *Chavica*, *Peperomia* (most species), and *Piper*. For details concerning the hypoderm in Hawaiian species of *Peperomia* see the account by Yuncker and Gray (2501) and for that of *P. berteroana* Miq. Skottsberg's (2124) description. Hypoderm varying considerably in thickness in different species of *Peperomia*, attaining as much as 15 layers of cells in some instances, or, with the epidermis, exceeding the thickness of the remainder of the leaf. No hypoderm differentiated in *P. hispidula* A. Dietr. according to Johnson (1183). Component cells of the hypoderm of *Piper betle* Linn. exhibit folded lateral walls when wilted, according to Chibber (393). The 'delicate cross bands' observed by Skottsberg (2124) in some of the hypodermal cells of *Peperomia berteroana* are probably of a similar nature. **Hydathodes** (Fig. 270 C–D) found by Yuncker and Gray (2501) to be common on both surfaces of the leaves of Hawaiian species of *Peperomia*; also recorded by Skottsberg (2124) in *P. berteroana*.

Mesophyll including a single layer of short, funnel-shaped, palisade cells in the Brazilian species of *Peperomia*; 1–3 layers of small, closely packed cells representing the palisade tissue recorded by Yuncker and Gray (2501) in Hawaiian species of *Peperomia*; a single layer of isodiametric to short cylindrical cells observed by Skottsberg (2124) in *P. berteroana*; palisade tissue said to be absent from *P. dolabriformia* H. B. et K. and *P. nivalis* Miq. For particulars concerning the structure, in a number of species of *Peperomia*, of the epidermis, hypodermis, and palisade cells in relation to light and carbon assimilation see the article by Schürhoff (2056).

Petiole (Fig. 271 A, C, I) of *Piper betle*, in transverse sections through the distal end, described by Chibber (393) as exhibiting a variable outline, the vascular system consisting of a crescent or almost closed circle of separate bundles, the centre of the petiole being occupied by a large mucilage canal (see also 'Mucilage Canals' on p. 1122). Vascular system similar in the petiole of *Piper excelsum* Forst. (Fig. 271 A) and *P. nigrum* Linn. (Fig. 271 I), but a few of the abaxial bundles tending to assume a 'medullary' position in *P. excelsum*. Three vascular bundles present in the petiole of *Peperomia hispidula* A. Dietr. (Johnson 1183) and *P. langsdorfii* Miq. (Fig. 271 C). Skottsberg (2124) observed

5 vascular bundles in the half-moon-shaped transverse section of the petiole of *P. berteroana*.

Crystals mostly in the form of small needles (Fig. 270 A), but more finely divided deposits resembling sand also occur, e.g. in the petiolar ground-tissue of *Piper betle*. Cluster crystals present in the mesophyll of *Peperomia*, and in small cells in the epidermis of *Symbryon*. Large solitary crystals recorded only in the veins of *Symbryon*. **Secretory cells** (see also under 'Axis'), sometimes appearing as transparent or opaque dots, present in the leaf of at least some species of all the investigated genera with the exception of *Symbryon*. Secretory cells mostly spherical, with suberized walls, and filled with clear or, more rarely, brown contents. **Mucilage canals** present in the petiole and extending throughout the leaf recorded in many of the species of *Piper* investigated by Van Tieghem (2319). Mucilage canals in the leaf described by the same author as not directly connected to those in the stem. (See also under 'Petiole', p. 1121.)

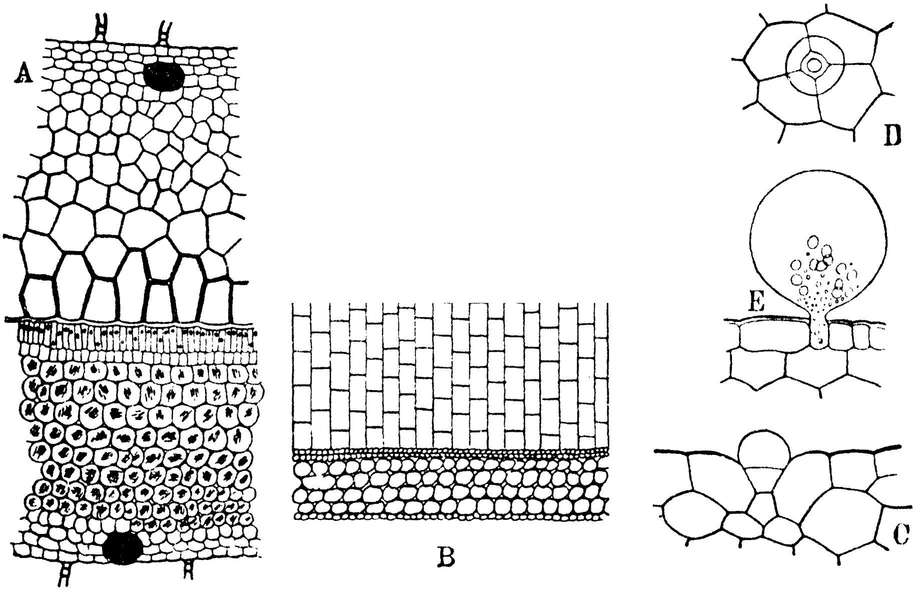


FIG. 270. *PIPERACEAE*

A, Transverse section of the leaf of *Peperomia incana* Dietr. B, Transverse section of the leaf of *P. pereskiaefolia* H. B. et K. C–D, Hydathodes of *P. incana*. E, Pearl-gland of *Piper* sp.—B after Pfitzer, E after Nestler, the remainder by Solereder.

AXIS

STEM (Fig. 271 F, H, J)

Cork arising in the epidermis or outer part of the cortex in *Peperomia* and *Piper*. **Hydathodes** present in all Hawaiian species of *Peperomia* examined by Yuncker and Gray (2501). Outer part of the primary **cortex** including a continuous ring or isolated patches of collenchyma in *Peperomia* and *Piper*. Collenchymatous ring in *Piper* sometimes including isolated fibres or becoming wholly converted to sclerenchyma, the ring being ruptured during subsequent growth in thickness. Cortical collenchyma ranging from 2 to 23 cells wide in the different Hawaiian species of *Peperomia*. Cortex of *Piper iaborandi* Vell. including scattered stone cells.

Endodermis developed to varying degrees in different species of *Piper*. According to Bond (224) the endodermis in the aerial stem of *Piper* is developed only in association with the outer ring of vascular bundles. In some species the endodermis forms a continuous cylinder around the bundles; in others it is replaced by a layer of relatively large cells with no casparian thickenings; in a third group of species it is present, but inconstantly distributed. The endodermis is differentiated at a short distance behind the growing-stem apex, the casparian thickenings first appearing opposite the vascular bundles. Bond tentatively concluded that the endodermis is a vestigial structure of no primary importance in the internal economy of the stem. No definite endodermal layer noted by Yuncker and Gray (2501) in Hawaiian species of *Peperomia*.

Pith of *Piper betle* Linn. including scattered stone cells. **Secretory cells** (see also under 'Leaf') present in the soft tissues. One or more **mucilage canals** with wide lumina present in the ground-tissue of a few species of *Piper*. Their development and distribution have been described by Van Tieghem (2319). In some species there is one large central canal accompanied by a variable number of smaller, more peripheral ones; in other species, only the central canal is present, whilst in a third group there are no mucilage canals at all. The mucilage canals in the stem are not directly continuous with those in the roots. (See also under 'Vascular System', below.) Cells resembling mucilage canals recorded by Yuncker and Gray (2501) in *Peperomia oahuensis* C. DC. **Crystals,** mostly clustered, present in the ground parenchyma of all of the Hawaiian species of *Peperomia* examined by the same authors, but varying in frequency in the individual species. Skottsberg (2124) observed plentiful crystals in various forms, including occasional druses, in the ground-tissue of *P. berteroana* Miq.

Vascular system, when seen in transverse sections through young internodes, appearing as widely spaced, and frequently scattered bundles, often with the xylem vessels arranged in U-shaped groups, the structure recalling that of the Monocotyledons. Several more or less distinct types occur of which the following are examples.

(i) *Piper betle* Linn. A peripheral ring of bundles present, bounded internally and separated from the pith by a sinuous zone of sclerenchyma. Outer margin of the phloem strands also accompanied by sclerenchyma. Remaining vascular strands more or less scattered and embedded in the thin-walled pith, each bundle growing in thickness to a limited extent. A central, and up to about 12 peripheral, mucilage canals present according to Chibber (393).

(ii) *Piper methysticum* Forst. Structure similar to that of *P. betle*. The course of the bundles has been described by Hoffstadt (984) as follows. The foliar bundles, after entering the stem, remain peripheral throughout the internode and then lie in the pith throughout the next 2 lower internodes. The stem enlarges to some extent by cambial activity, but also by the division of some of the pith cells. Interfascicular cambium arises in the internode at a late stage and cuts off segments only on one side; in the nodes it arises even more tardily.

(iii) ***Piper nigrum*** Linn. (Fig. 271 H). Structure fundamentally similar to that of *P. betle*, but medullary bundles arranged more definitely in a circle.

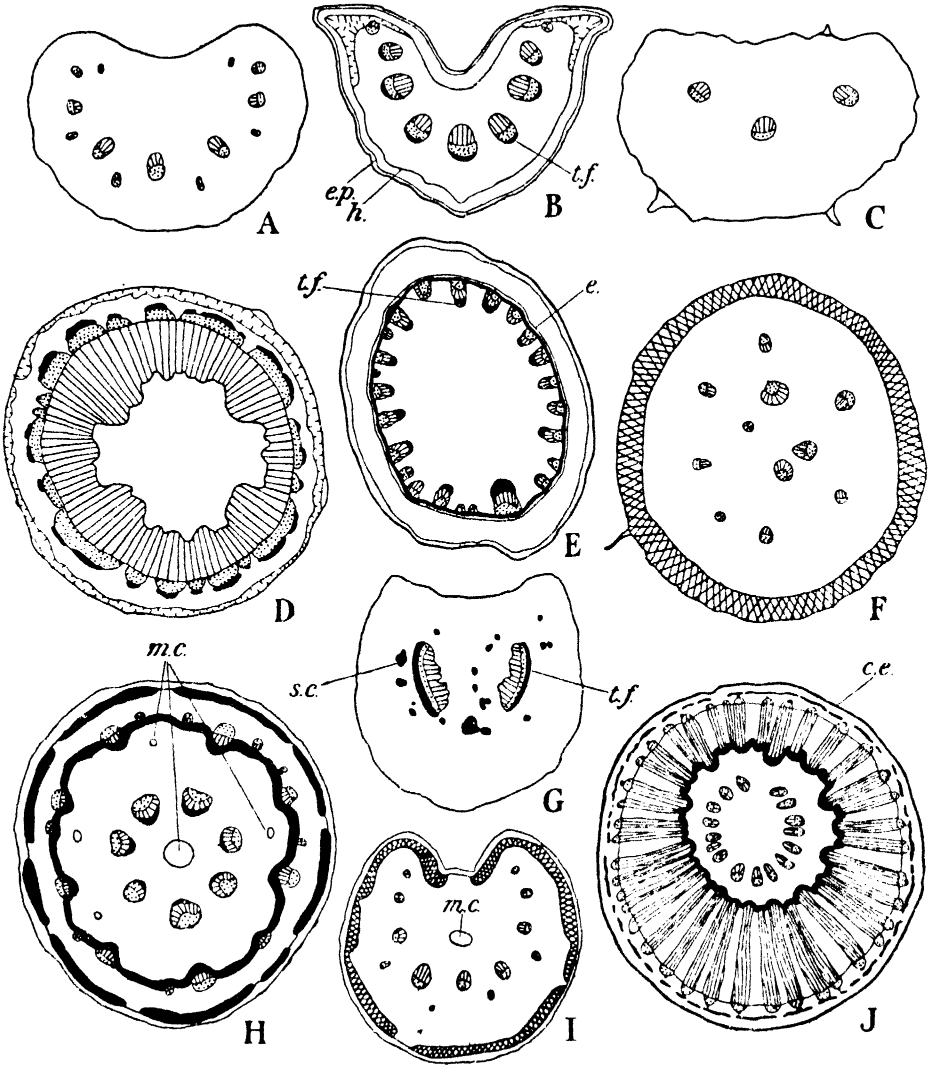


FIG. 271. *PIPERACEAE*, A, C, F, and H–J; *SAURURACEAE*, B and E; *CHLORANTHACEAE*, D and G

A, ***Piper excelsum*** Forst. Petiole ×11. B, *Houttuynia cordata* Thunb. Petiole ×20. C, *Peperomia langsdorfii* Miq. Petiole ×30. D, *Chloranthus officinalis* Blume. Stem ×14. E, *Houttuynia cordata* Thunb. Stem ×13. F, *Peperomia langsdorfii* Miq. Stem ×10. G, *Chloranthus officinalis* Blume. Petiole ×11. H, ***Piper nigrum*** Linn. Stem ×14. I, *P. nigrum* Linn. Petiole ×15. J, *P. excelsum* Forst. Stem ×18.

c.e. Cutinized epidermis. *e.* Endodermis. *e.p.* Epidermis. *h.* Hypodermis. *m.c.* Mucilage canals. *s.c.* Stone cells. *t.f.* Thin-walled fibres.

A ring of 4 or more secretory canals embedded in the pith, outside the circle of medullary bundles, and a solitary canal at the centre of the stem.

(iv) *Piper jaborandi* Vell. Differing from *P. betle* in the peripheral circle of bundles not being separated from those in the pith by a ring of sclerenchyma; mechanical support provided by a ring of sclerenchyma in the pericyclic region external to the outer ring of vascular bundles. Xylem groups in mature stems becoming radially elongated, as seen in transverse sections, owing to cambial activity, but remaining separated from one another by broad, unlignified, primary medullary rays. Individual bundles supported by caps of sclerenchyma where abutting on the pith. Vessels with horizontally elongated to scalariform lateral pits. Some vessel members with very tapering, overlapping ends, and devoid of well-defined perforations. A large canal occupies most of the phloem in each of the medullary bundles.

(v) *Piper excelsum* Forst. (Fig. 271 J). Structure as in *P. jaborandi*, but with a sclerenchymatous ring at the inner boundary of the radially elongated xylem groups. Small, inconspicuous, secretory canals present in the ground-tissue between the outer and inner rings of bundles.

(vi) *Piper fluminense* C. DC. Peripheral vascular bundles much smaller than and separated from those in the pith by a sclerenchymatous ring. Other small bundles irregularly distributed in the ground-tissue.

(vii) *Peperomia* spp. (Fig. 271 F). Vascular system consisting of scattered bundles embedded in the parenchymatous ground-tissue, or, in some species, with the bundles organized into more or less distinct circles. Stem of Hawaiian species of *Peperomia* described by Yuncker and Gray (2501) as exhibiting an outer, more or less well-defined but irregular ring of vascular bundles, surrounding a central group of scattered bundles. This applies also to *Peperomia langsdorfii* Miq. (Fig. 271 F) examined at Kew. Outer vascular bundles arranged in a ring, sometimes surrounding a second or even third ring, the central strands alone being scattered in *P. berteroana* according to Skottsberg (2124). *P. deliculata* Hench. is said to show a single ring of 4 bundles, and *P. tenera* Miq. a single, axile, vascular strand. Johnson (1183) has recorded 10 or 12 bundles in 2 concentric rings in '*P. verticillata*'. The same author has also described how, in *P. hispidula* A. Dietr., the stele consists of only about 150 cells in transverse sections, and has 2 distinct groups of primary xylem, one near each end of the flattened bundle. No evidence of the formation of secondary xylem and phloem was observed.

The course of the vascular bundles in certain species of *Peperomia* and *Piper* has been described in detail by Rousseau (1962).

WOOD (Fig. 272 E–H)

Vessels usually moderately small (50–100 μ mean tangential diameter), sometimes rather larger or smaller; solitary and in small multiples and sometimes with a tendency to irregular clusters in *Piper*; 5–12 per sq. mm. Perforations typically simple, but Solereder (quoting Debray) refers to occasional scalariform plates with few bars in *Piper*, and Record (1886, 533) also mentions a tendency to scalariform perforation plates in this genus. Intervascular pitting alternate, small to minute in *Piper*, moderately large in *Peperomia*; pits to parenchyma mostly similar to the intervascular pitting in *Piper*, but with many narrow elongated pits in some species, commonly large, simple, and almost scalariform in *Peperomia*. Vessels seldom in contact with the rays, particularly in *Piper*. Mean member length 0·2–0·4 mm. **Parenchyma**

paratracheal, forming narrow, but usually complete, sheaths round the vessels or vessel groups in *Piper* (Fig. 272 E), rather less abundant in *Peperomia*. Strands of 2–4 cells. Storied in *Piper*. **Rays** up to 8 cells wide in *Peperomia*, commonly up to 30–40 cells wide in *Piper*, and up to 0·75 mm. wide in *P. smilacifolium* C. DC.; rays exceptionally high, extending the full length of the internodes; uniseriates absent; 2–6 rays per mm.; composed almost entirely of square and upright cells, but with a few small procumbent cells scattered among these (Fig. 272 G); with sheath cells. With numerous, small, solitary crystals in *Peperomia*. Oil or mucilage cells present in some species of *Piper*, e.g. *P. elongatum* Vahl. **Fibres** with simple pits, which are either equally numerous in both tangential and radial walls, or mostly in the radial walls, sometimes with markedly funnel-shaped canals in *Piper*; occasionally septate; walls moderately thin to moderately thick. Sometimes storied in *Piper*. Mean length 0·5–0·75 mm.

ROOT

Root of *Piper betle* Linn. described by Chibber (393) as showing 6 xylem plates, bifurcated once or twice and radiating from the centre, the plates being separated by broad, sometimes as much as 12-seriate, rays. Stele in the same species bounded externally by a ring of sclerenchyma 1 cell thick. Primary vascular structure diarch in small, but tetrarch in large roots of *Peperomia berteroana* Miq. according to Skottsberg (2124). **Cork** and **cortex** well developed. **Secretory cells** infrequent compared with those in the stem, their walls being lignified or suberized. **Mucilage canals** absent. The presence of an endotrophic, possibly **mycorrhizal, fungus,** forming coiled tangles of hyphae with bead-like swellings, recorded by Johnson (1183) in the cortex, immediately external to the endodermis, of the delicate, sparsely branched roots of *P. hispidula* A. Dietr. Vascular system in the same species very simple, diarch. **Root hairs** present in young roots, but replaced in old roots by several layers of secondary cortical cells in *P. berteroana* according to Skottsberg (2124).

TAXONOMIC NOTES

The Piperaceae are of interest anatomically because of their vascular system of widely spaced and often scattered bundles which recalls that of the Monocotyledons. It is noteworthy, however, that the Piperaceae, unlike the Monocotyledons, grow in thickness through cambial activity. It may also be noted that Hutchinson (1113) believes the Piperales to have been derived from a ranalian stock.

Taxonomists commonly agree that the Piperaceae, Saururaceae, and Chloranthaceae are related to one another, an opinion which is fully confirmed by anatomical evidence. Some authors, such as Rousseau (1962), have gone so far as to affirm that these 3 families are so closely related that they should be amalgamated. Rousseau also concluded that the structure of the Piperaceae *sensu stricto* is a fundamental type from which that in *Saururus* and *Chloranthus* has been derived by minor, and that in *Peperomia* by major, modifications. In other words, he finds *Chloranthus* and *Saururus*, which are generally regarded as belonging to families which are distinct from the Piperaceae, to be more like *Piper* than is *Peperomia* which belongs to the Piperaceae *sensu stricto*.

The woods of the Piperaceae and Chloranthaceae examined by the author are by no means uniform in their structure. Those of the Piperaceae are more highly specialized and that of *Piper*, with its minute intervascular and vessel-parenchyma pitting and storied structure, is outstanding in this group.

ECONOMIC USES

Black and White Pepper are obtained, chiefly in India and the Malay Peninsula, from the fruits of *Piper nigrum* Linn. A beverage is prepared in the Society and South Sea Islands from Kava Root derived from *P. methysticum* Forst. Cubebs, used in medicine and as a condiment, are the dried, unripe fruits of *P. cubeba* Linn. f.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Chavica, Peperomia,* Piper,* Symbryon.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Peperomia, Piper.

LITERATURE

(i) *On General Anatomy*

Bond, G. **224**, Chibber **393**, de Candolle **554**, Hoffstadt **984**, Hutchinson **1113**, Ironside **1123**, Johnson **1183**, Lehmann **1343**, Rousseau **1962**, Schürhoff **2056**, Skottsberg **2124**, **2125**, Van Tieghem **2319**, Yuncker and Gray **2501**.

(ii) *On Wood Structure*

Burgerstein **310**, **312**, Cozzo **494**, Dadswell and Record **533**, Pfeiffer, H. **1712**, Record **1809**, **1843**, **1851**, Record and Hess **1886**, Tupper **2295**, Williams **2430**.

225. SAURURACEAE

(FIG. 271 on p. 1124)

SUMMARY

A small Malayan family of perennial herbs, closely related and anatomically similar to the Piperaceae, but with the **vascular bundles,** although widely spaced, less scattered than in the last family. **Secretory cells** are present and often abundant in the ground-tissue. Their mode of development in *Saururus* has been described in detail by Lehmann (1343). Cluster **crystals** common. The following particulars refer, except where otherwise stated, to *Houttuynia cordata* Thunb. cultivated at Kew.

LEAF

Dorsiventral. **Stomata** very numerous on the lower but only occurring sporadically on the upper surface; surrounded by a rosette of epidermal cells. **Hypoderm** consisting of a single layer of very large cells with pale-green contents, present beneath the upper epidermis. Cells immediately on the inside of those of the lower epidermis also differentiated as a distinct hypoderm, some of them serving as secretory cells with yellowish-green contents. **Mesophyll** including 1–2 layers of rather loosely arranged palisade cells and a region of spongy tissue. Vascular bundles of the **veins** not accompanied by **sclerenchyma**, but surrounded by secretory cells with contents similar to those in the hypodermal layer on the lower side of the leaf. **Petiole** (Fig. 271 B), in transverse sections through the distal end, exhibiting a crescent of 7 or more widely spaced vascular bundles. Abundant **secretory cells** and frequent cluster **crystals** present in the petiolar ground-tissue.

AXIS

STEM (Fig. 271 E)

Primary **cortex** about 10 cells wide, bounded internally by a very definite ring of thick-walled fibres in the **pericycle. Vascular bundles** widely spaced, of the same type as those in the Piperaceae, but arranged in a single circle with phloem groups abutting directly on the pericyclic sclerenchyma. **Xylem** in each bundle including a U-shaped group of thin-walled vessels, the individual elements being up to about 45 μ in radial diameter or occasionally larger. Vessels with rather large, horizontally elongated, bordered pits. Ends of the vessel members tapering; scalariform perforations. **Pith** broad, parenchymatous. Elongated, thin-walled **secretory cells,** mostly arranged in axial rows, scattered throughout the cortex and pith. Clustered **crystals** frequent in the ground-tissue.

Stem structure similar in *Saururus cernuus* Linn. judging from the few facts recorded by Solereder, but the individual bundles in this species are each surrounded by sclerenchyma as well as united by a ring of similar tissue in the pericyclic region. Two circles of vascular bundles recorded in *Saururus cernuus* by Holm (1012). For details concerning the course of the vascular bundles in the stem of *Saururus* see Rousseau's (1962) article.

ROOT

Pentarch in *Saururus cernuus* Linn. according to Holm (1012).

TAXONOMIC NOTES, *see under* Piperaceae, p. 1126.

GENERA DESCRIBED

Houttuynia,* Saururus.

* Represented in the Kew slide collection.

LITERATURE

On General Anatomy

Holm **1012**, Lehmann **1343**, Rousseau **1962**.

226. CHLORANTHACEAE

(FIG. 271 on p. 1124; FIG. 272 on p. 1130)

SUMMARY

(i) GENERAL

A tropical and south temperate family of herbs, shrubs, and trees which are usually aromatic on account of material contained in **secretory cells** in the leaf and axis. The distribution of the secretory cells is of generic diagnostic value according to Thierry (2248). Skutch (2126) has drawn attention to

Hedyosmum arborescens Sw. and related species because of the presence of a sheath surrounding the stem for some 15 mm. above each node. The sheath, which consists of collenchyma and is formed from the connate bases of the opposite leaves, supports the stem during intercalary growth. Lateral branches are initiated in the leaf axils, but, when mature, are attached to the parent axis some 27 mm. above the node and thus above the top of the axillary sheath. Cork, formed on the inner surface of the sheath, serves to bring the latter into intimate contact with the stem. There is a pulvinus on the stem at the upper margin of the sheath.

(ii) WOOD

Vessels small, tending to be exclusively solitary apart from overlapping ends, perforation plates very long, scalariform and with very numerous fine bars, intervascular pitting scalariform and pits to parenchyma similar; members moderately to extremely long. **Parenchyma** either diffuse or scanty paratracheal. **Rays** high and broad, 8–10 cells wide, composed almost entirely of square or upright cells or of upright cells only. **Fibres** with distinctly bordered or simple pits, of medium length to moderately long.

LEAF

Dorsiventral, but the palisade tissue represented only by short arm-cells in *Ascarina*, *Chloranthus*, *Hedyosmum*. Spongy mesophyll including large intercellular spaces; slightly sclerosed at certain points in *Hedyosmum*. Cells of the lower **epidermis** particularly small in species of *Ascarina*; those of *A. rubricaulis* Solms provided with crested papillae. **Stomata** confined to the lower surface; surrounded by variously arranged epidermal cells. A single-layered **hypoderm** present beneath the upper epidermis of species of *Ascarina* and *Hedyosmum*, a similar tissue being confined to the neighbourhood of the veins in other species of *Hedyosmum* and in several of *Chloranthus*. Groups of **silicified cells** in the epidermis and adjacent mesophyll recorded in *Hedyosmum*. Vascular bundles of the **veins** sometimes surrounded by a sclerenchymatous sheath, and the smaller ones by slightly sclerosed parenchyma. Sclerenchymatous sheath interrupted in species of *Chloranthus*, and absent from species of *Hedyosmum*. **Petiole** of *Chloranthus officinalis* Blume (Fig. 271 G), examined at Kew, exhibiting, in transverse sections through the distal end, a deeply crescentic, somewhat interrupted, vascular strand. Vessels of the xylem in very definite radial rows. Large stone cells, solitary and in small groups, scattered throughout the parenchymatous ground-tissue of the petiole in the same species. **Mucilage canals** present in the petiole and larger veins of *Hedyosmum arborescens* Sw. Spherical **secretory cells** (see also under 'Axis'), sometimes appearing as transparent dots, present in all investigated species. **Crystals** not known to occur in the leaf apart from small solitary types in the upper epidermis of *Chloranthus inconspicuus* Sw.

AXIS

YOUNG STEM (Fig. 271 D)

Cork formation not observed. **Pericycle** containing a composite, continuous ring of sclerenchyma in *Chloranthus brachystachys* Blume; isolated strands of fibres present in the corresponding position in *Chloranthus*

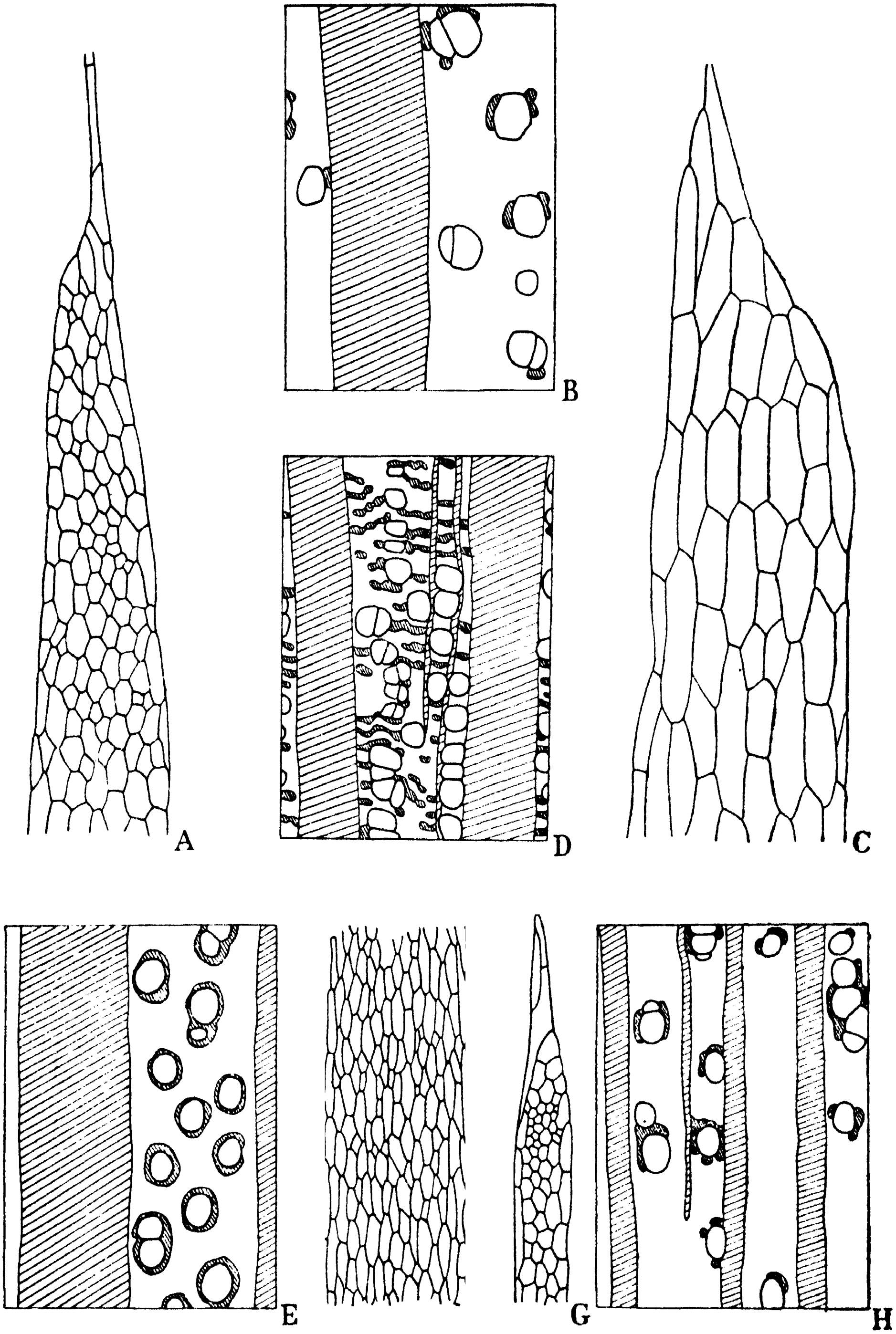


FIG. 272. *CHLORANTHACEAE*, A–D; *PIPERACEAE*, E–H

A, *Ascarina lanceolata* Hook. f. B, *Hedyosmum scaberrimum* Standl. C, *H. scaberrimum* Standl. D, *Ascarina* sp. E, *Piper smilacifolium* C. DC. F, *P. elongatum* Vahl. G, *Peperomia bueana* C. DC. H, *P. bueana* C. DC.

officinalis Blume and *Hedyosmum brasiliense* Mart. **Xylem** of *Chloranthus officinalis* (Fig. 271 D) seen to be in the form of a continuous cylinder, but traversed by rays 1–8 cells wide composed of thick-walled, lignified cells, not very different in transverse diameter from the vessels, and containing abundant starch. Vessels somewhat angular, arranged in very definite radial rows and up to about 30 μ in diameter. Vessels with scalariform perforation plates. Other details as described under 'Wood'. **Pith** fairly broad, consisting of thin-walled, axially elongated, amyliferous cells, appearing somewhat collenchymatous in transverse sections. **Secretory cells,** similar to those in the leaf, present in the cortex and pith; walls of the cells suberized. **Mucilage canals** occur at the margin of the pith in several species of *Hedyosmum*; those of *H. brasiliense* containing sphaerocrystalline masses in addition to mucilage. Small clustered **crystals** recorded in the inner part of the cortex in *H. brasiliense.*

WOOD (Fig. 272 A–D)

Vessels small (less than 100 μ mean tangential diameter); often exclusively solitary, apart from apparent tangential pairs due to overlapping ends, but with moderately numerous small multiples in some specimens. Perforation plates scalariform, very oblique and with very many (up to 100 or more) fine bars. Intervascular pitting scalariform to transitional, pits to ray and wood parenchyma similar. Mean member length 0·8 mm. in *Chloranthus* (100) to 2·0 mm. in *Hedyosmum.* **Parenchyma** predominantly apotracheal in *Ascarina*, as scattered cells and irregular, short, uniseriate lines (Fig. 272 D); paratracheal in *Hedyosmum*, as incomplete sheaths round the vessels (Fig. 272 B). Strands usually of 4–6 very high cells. **Rays** up to 8–22 cells wide; sometimes up to 1 mm. wide in *Hedyosmum*; often up to 10 mm. high; uniseriates moderately numerous, except in *Hedyosmum*, and composed of very high upright cells; 6–12 rays per mm. in *Ascarina*, about 2 per mm. in *Hedyosmum*; the multiseriate rays composed almost entirely of square and upright cells, with very few procumbents, in *Ascarina*, and almost entirely of high upright cells in *Hedyosmum*; with 1–10 uniseriate marginal rows of upright cells; with sheath cells in *Ascarina.* **Fibres** with distinctly bordered pits in *Ascarina* and *Chloranthus* (2158), but with simple pits and occasionally septate in *Hedyosmum.* Walls moderately thick in *Ascarina*, rather thin in *Hedyosmum.* Mean length 0·9–2·1 mm.

TAXONOMIC NOTES

The relationship of the Chloranthaceae to the Piperaceae and Saururaceae in the light of anatomical evidence has been discussed by Thierry (2248) who concluded that the Chloranthaceae and Saururaceae have more points in common with each other than either family has with the Piperaceae.

The woods of *Ascarina* and *Hedyosmum* are of a very unspecialized type and in this respect contrast with those of the Piperaceae. *Ascarina* differs from the other genera of these 2 families in having diffuse parenchyma.

The genus *Circaeaster*, which was included in the Chloranthaceae in the Bentham and Hooker system, differs from all the other genera in the absence of secretory cells. It is described separately in the family Circaeasteraceae, p. 63.

Genera Described

(i) For General Anatomy

Ascarina, Chloranthus,* Hedyosmum.

* Represented in the Kew slide collection.

(ii) For Wood Structure

Ascarina, (Chloranthus), Hedyosmum.

Literature

(i) *On General Anatomy*

Rousseau **1962**, Skutch **2126**, Thierry **2248**.

(ii) *On Wood Structure*

Bailey **100**, den Berger **182**, Dadswell and Record **533**, Record **1843**, **1851**, Record and Hess **1886**, Tupper **2295**, Williams **2430**.

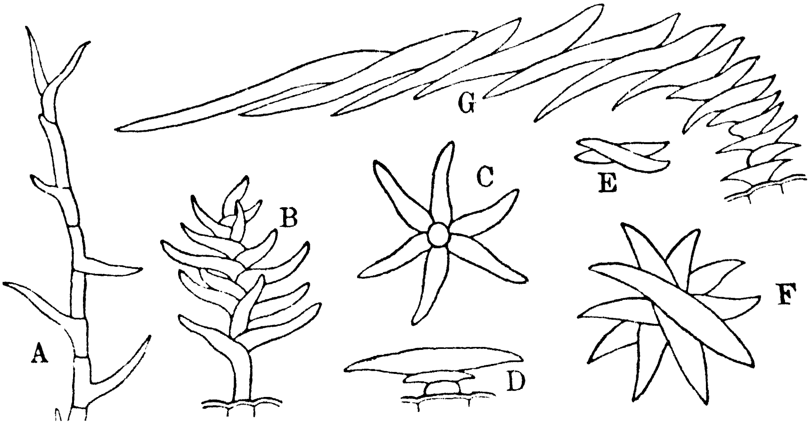


Fig. 273. *MYRISTICACEAE*

Hairs of: A, '*Knema hookeriana* Warb.' (leaf). B–C, *Virola sebifera* Aubl. (leaf): B, Trichome seen from the side; C, seen from above. D–E, *Dialyanthera otoba* Warb. (inflorescence): D, Trichome from the side; E, from above. F, *Myristica cookii* Warb. (leaf): trichome from above. G, *Myristica villosa* Warb. (leaf).—After Warburg.

227. MYRISTICACEAE

(Fig. 273 on p. 1132; Fig. 274 on p. 1134)

Summary

(i) General

A tropical family of trees which are frequently aromatic. The **hairs** exhibit the diversity of forms shown in Fig. 273, but all of these may be regarded as variations of sympodially branched, uniseriate trichomes. The **stomata,** which are rubiaceous, have not received much attention, but have been recorded only on the lower surface. In the axis, the **cork** arises superficially and the inner part of the primary **cortex** and the secondary **phloem** include sclerenchymatous elements. Vestiges of **intraxylary phloem** have been recorded in the leaf and peduncle of *Myristica* by Worsdell (2468). One of the most characteristic features is the presence of spherical **secretory cells** in both leaf and axis. These presumably secrete the aromatic material to which the perfume of the plants is due. **Tannin** is also abundant in the tissues, where it sometimes occurs in special sacs. **Crystals** are typically acicular, but clustered types also occur.

(ii) WOOD

Vessels mostly medium-sized, solitary and in small multiples, perforation plates typically simple and scalariform, the latter probably always present but rather rare in certain species, abundant in others, with few bars; sometimes exclusively scalariform; a few reticulate or compound scalariform perforation plates often present; intervascular pitting varying from scalariform to alternate, the latter large or small; pits to parenchyma commonly large, and often elongated; members moderately to very long. **Parenchyma** paratracheal, scanty to almost vasicentric; narrow to broad terminal bands often present and a little diffuse parenchyma reported in a few species. Occasionally with oil cells or sclerosed. **Rays** typically up to 2–3 cells wide, usually markedly heterogeneous, oil or mucilage cells sometimes present; with distinctive **tanniniferous tubes** in occasional rays of all species. **Fibres** usually with simple pits, commonly septate round the vessels and sometimes at the ring-boundaries, of medium length to moderately long.

LEAF

Dorsiventral in *Virola officinalis* Warb., the palisade tissue consisting of several layers of long cells. **Hairs,** although exhibiting the diversity of forms shown in Fig. 273, represent modifications of sympodially branched uniseriate trichomes. Glandular hairs not recorded. Lower **epidermis** frequently papillose. **Hypoderm** recorded beneath the upper epidermis in *Dialyanthera.* **Stomata** confined to the lower surface in species of *Virola*; rubiaceous. **Mesophyll.** Sclerenchymatous fibres recorded in *Gymnacranthera,* and branched, frequently stellate, sclerenchymatous idioblasts in *Iryanthera.* Smaller **veins** vertically transcurrent by unlignified tissue in *Virola officinalis*; the large bundles in the same species also unaccompanied by sclerenchyma. A few strands of **intraxylary phloem** in the midrib and petiole of *Myristica fragrans* Hoult. recorded by Worsdell (2468). Spherical **secretory cells** (see also 'Axis') with yellow, red, or brown, semi-liquid or crystalline contents, present in various parts of the mesophyll in numerous species. Walls of the secretory cells, in *M. officinalis* Mart., often showing distinct differentiation into an outer suberized and an inner cellulose lamella; sometimes strongly thickened and mucilaginous in other members of the same genus. Elongated **tanniniferous sacs** (see also 'Axis') also present in the veins. Small acicular **crystals** occur in the same region; cluster crystals sometimes present as well in the sub-epidermis.

AXIS

YOUNG STEM

Cork arising in the outer part of the cortex in *Myristica macrophylla* Spruce and *Virola officinalis* Warb.; outer walls of some of the component cells sclerosed on one side. Primary **cortex** of *Myristica macrophylla* seen to be

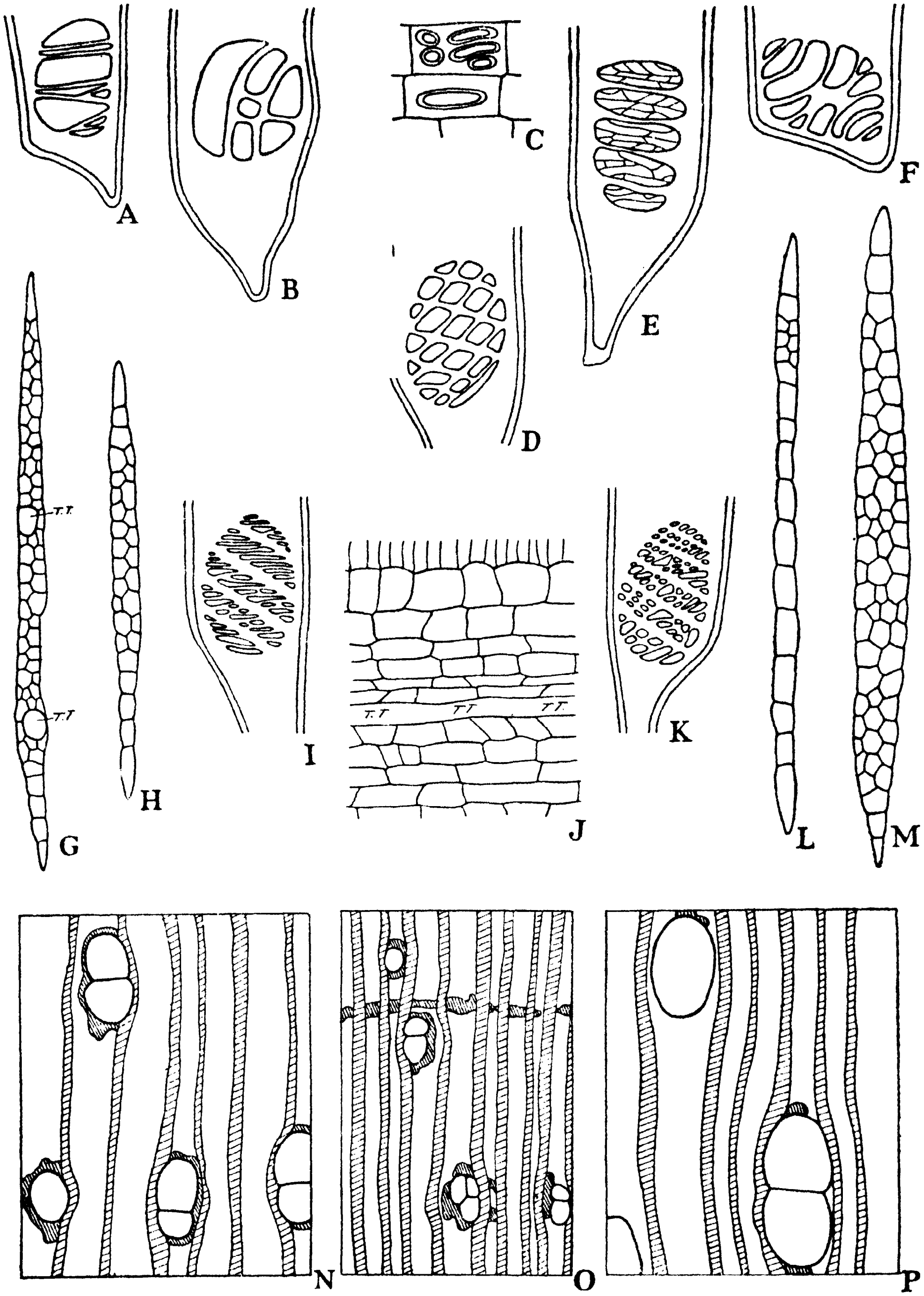


FIG. 274. *MYRISTICACEAE*

A, *Coelocaryon oxycarpum* Stapf. Perforation plate × 100. B, *C. oxycarpum* Stapf. Perforation [illegible]

Warb. I, *Iryanthera leptoclada* Markgraf. Perforation plate × 100. J, *Cephalosphaera usambarensis* Warb. Radial section of ray × 90. K, *Iryanthera leptoclada* Markgraf. Perforation plate × 100. L, *Compsoneura sprucei* Warb. M, *Horsfieldia bracteosa* M. R. Henderson. N, *Cephalosphaera usambarensis* Warb. O, *Compsoneura sprucei* Warb. P. *Dialyanthera otoba* Warb. Figs. A, B, D, E, F, I, and K after Garratt (746).

T.T. [illegible]

somewhat spongy, and to include axial rows of stone cells. **Pericycle** in the same species including large but widely spaced strands of very thick-walled fibres. Secondary **phloem** containing fibres or a mixture of fibres and stone cells; sometimes becoming stratified into hard and soft portions in relatively old material. **Xylem** in *M. macrophylla* in the form of a continuous cylinder traversed by narrow rays; vessels rather unevenly distributed, a few solitary, but mostly in radial rows, diameter up to about 60 μ. Wood parenchyma in the same species composed of elements with wide lumina, and approximately quadrangular in transverse sections. For nature of pitting and vessel perforations see 'Wood'. Vestiges of **intraxylary phloem** observed by Worsdell (2468) in the peduncle, but not in the vegetative axis, of *M. fragrans* Hoult. **Pith** of *M. macrophylla* very heterogeneous, including parenchymatous cells, axial rows of somewhat elongated stone cells and local groups of much larger, irregularly shaped stone cells with very thick walls. **Secretory elements.** Tanniniferous sacs (see also under 'Leaf'), with red or brown contents in dead material, but filled with aqueous or bright-yellow inclusions when alive, recorded by Solereder at the margin of the pith and in the phloem. Secretory cavities, particularly in the phloem, observed in *M. macrophylla*, and secretory cells in the unlignified tissues of the same species. Numerous acicular **crystals** present in the cortex.

WOOD (Fig. 274)

Vessels most commonly medium-sized (100–200 μ mean tangential diameter), but sometimes distinctly smaller or rather larger in individual species of many of the genera; solitary and in multiples of 2 or 3 cells; typically 2–6 per sq. mm., but sometimes more numerous; Garratt (746) gives a maximum of up to 15–18 per sq. mm. in occasional specimens of *Compsoneura*, *Iryanthera*, *Knema*, and *Virola*, all of which he also lists as sometimes having small vessels. Perforation plates typically both simple and scalariform, with occasional reticulate or 'compound scalariform' plates present in most genera; the scalariform plates moderately oblique and usually with 1–10 broad bars, but occasionally with up to 20 (746), the reticulate plates very varied in type (Fig. 274 A–B, D–F, I, and K), best developed, according to Garratt, in *Iryanthera* and rare in *Knema* p.p. and *Dialyanthera*; some scalariform plates always present, but very rare in some specimens of *Horsfieldia*, *Pycnanthus*, and *Virola*; simple perforations sometimes very rare or absent, e.g. in some species of *Gymnacranthera* and *Knema*. Intervascular pitting varying from scalariform in some species of *Coelocaryon* and transitional between scalariform and opposite (with the elongated pits very narrow) in some species of *Gymnacranthera*, *Iryanthera*, and *Knema*, to alternate and large in *Cephalosphaera*, *Horsfieldia*, and *Pycnanthus*, or alternate and small in *Myristica* and *Virola*; the pitting unusually variable in different species of the same genus and even in individual vessels in a single specimen. Pits to ray and wood parenchyma commonly wide and oval or elongated horizontally (Fig. 274 C), usually distinctly bordered, occasionally simple.. Solid contents and tyloses sometimes present, the latter, according to Garratt, sclerosed and pitted in some species of *Gymnacranthera*, *Iryanthera*, and *Staudtia*. Mean member length 1·0–1·3 mm. **Parenchyma** (*a*) paratracheal, often rather sparse and varying from a few cells to narrow sheaths round the vessels, present in all the genera examined, but very sparse in *Dialyanthera otoba* Warb. and some species of *Virola*. Garratt (746) notes that this parenchyma is usually limited to the inner and outer surfaces of the vessels or vessel groups and that in this position there is often a single cell that is characteristically larger and rectangular in shape (Fig. 274 P); (*b*) terminal, in bands 2 to several cells wide, present in most of the genera, but absent, according to Garratt, from some species of *Brochoneura*, *Cephalosphaera*, *Coelocaryon*, *Dialyanthera*, *Horsfieldia*, *Myristica*, *Pycnanthus*, *Staudtia*, and *Virola*; (*c*) diffuse, occasionally present, according to Garratt, particularly in the neighbourhood of the ring-boundaries in species in which the rings are marked by septate fibres, e.g. in some species of *Horsfieldia* and *Virola*. Strands most commonly of 8 cells, but often of more. Garratt notes oil or mucilage cells in *Knema alvarezii* Merr., sclerosed cells in *Gymnacranthera paniculata* (A. DC.) Warb., and brown deposits in many specimens. **Rays** typically 2–3 cells wide with the biseriate parts not much wider than the uniseriate; rarely almost exclusively uniseriate, e.g. in *Compsoneura*, and up to 3–6 cells wide in some species or specimens of *Compsoneura*, *Horsfieldia*, *Knema*, *Pycnanthus*, *Staudtia*, and *Virola*; about 1 mm. high or lower; typically curving round the vessels in cross-sections; uniseriates usually numerous, composed entirely of square or upright cells, or of mixed upright and procumbent cells, and entirely of procumbent cells in *Dialyanthera* and *Gymnacranthera*, very few in some genera, e.g. *Horsfieldia* and *Pycnanthus*; 6–15 rays per mm.; heterogeneous (Kribs's Type II A and B), all the cells usually rather large; commonly with 4–10 marginal rows of square or upright cells and sometimes with more, but less markedly heterogeneous in *Gymnacranthera*, *Horsfieldia*, *Iryanthera*, *Knema*, *Pycnanthus*, and *Virola*; almost homogeneous in some species of *Myristica* and *Virola*. Abundant crystals present in some species of *Horsfieldia* and *Iryanthera*. Oil or mucilage cells sometimes present, e.g. in *Knema alvarezii*, *Myristica elliptica* Wall., *M. hypargyraea* A. Gray, *M. guatteriaefolia* A. DC., *Virola merendonis*, and *V. panamensis* (Hemsl.) Warb. (746). Garratt (746) has observed tube-like structures, which he has termed **'tanniniferous tubes'**, in occasional rays of all the specimens he examined and states that, as far as is known, such tubes do not occur in the wood of any other family (Fig. 274 G and J, *T.T.*). The tubes are very long, lack pitting, and contain a tanniniferous substance, Kino, which is a yellow to reddish sap when fresh, hardening in a short time to a dark-red mass resembling sealing-wax. **Fibres** with numerous pits on the radial walls, typically simple, but sometimes with small borders, e.g. in some species of *Iryanthera*, *Scyphocephalium*, and *Virola*; typically septate in the neighbourhood of the vessels, but such fibres not observed in *Compsoneura*, *Horsfieldia*, and *Iryanthera*, and rare in *Knema*; Garratt notes septate fibres delimiting the growth rings in some species of *Horsfieldia* and *Virola*, and non-septate fibres containing deposits, which form rather heavy horizontal plates or more or less completely fill the lumina, in *Gymnacranthera*, *Horsfieldia*, *Iryanthera*, *Knema*, *Myristica*, *Staudtia*, and *Virola*; Janssonius (1154) refers to occasional septate fibres scattered among the non-septate. Walls usually thin, but thick in some species of *Brochoneura* (746), *Compsoneura*, *Iryanthera*, and *Staudtia* (746). Mean length usually 1·2–1·8 mm., but, according to Garratt, occasionally slightly more than 2·0 mm.

TAXONOMIC NOTES

(i) FROM WOOD STRUCTURE

From a study of 82 species of 15 genera, Garratt (746) draws the following conclusions with regard to the internal classification of the family.

(*a*) The secondary xylem presents an unusually unified structure throughout the family, the points of similarity including such striking features as the presence of 'tanniniferous tubes', a character believed to be entirely limited to this family.

(*b*) The wood anatomy supports Warburg's organization of the Myristicaceae into a number of distinct genera rather than de Candolle's or Bentham and Hooker's monogeneric treatment.

> 'While there is a definite similarity in the structure of the wood in a number of cases, the distinctions between most of the genera become clear when their natural geographical grouping is considered. This is especially true with the African and American Myristicaceae, the woods of which appear to be readily separable into the genera recognized by Warburg. Only among the Asiatic genera is there any consistent overlapping in anatomical features and even there *Horsfieldia* stands distinctly apart from the other three genera, *Gymnacranthera*, *Knema*, and *Myristica*.'

On the other hand, Janssonius (1154), discussing 8 Javanese species, which according to Warburg's classification include *Horsfieldia*, *Knema*, and *Myristica*, states that their similarity is greater than one usually finds in 8 species of 1 genus and that to find such similarity among 8 species belonging to 3 genera would be quite exceptional.

In a subsequent paper (747) Garratt discusses the external relationships of the family and its position in various 'natural' systems of classification. His main conclusions are as follows:

> 'The anatomy . . . lends definite support to the action of those systematic botanists who have placed the Myristicaceae close to the Lauraceae, since the general similarity between the woods of these two families is outstanding. With the other investigated families which Hutchinson has placed in the order Laurales, namely the Monimiaceae and Hernandiaceae, the affinities of the Myristicaceae are not nearly so clear. While there is some similarity to the woods of the Monimiaceae, the resemblance of the Nutmegs to the Hernandiaceae is far from striking; however, the Hernandiaceae do bear somewhat greater resemblance to the Lauraceae.'

Garratt also expresses the opinion that, while there is some indication of affinity with the Magnoliaceae, Schisandraceae, and Canellaceae, there is none at all with the Annonaceae, Eupomatiaceae, Menispermaceae, and Lardizabalaceae.

(ii) FROM GENERAL ANATOMY

Worsdell (2468), having demonstrated the occurrence of intraxylary phloem in the midrib of the leaf and in the peduncle of *Myristica*, concluded that this genus once had intraxylary phloem in the vegetative axis as well. He also expressed the view that the intraxylary phloem of the leaf is a relic of a system of complete medullary bundles which at one time occurred normally in both stem and leaf.

ECONOMIC USES

Fatty and oily substances, some of which resemble butter, are obtained from the fruits and seeds of various species of *Myristica*. Nutmegs are the seeds and Mace the arils of *M. fragrans* Hoult., which is widely cultivated in tropical countries.

Though several species grow to timber size, the woods, which are usually soft and perishable, appear to be little used.

Genera Described

(i) For General Anatomy

Dialyanthera, Gymnacranthera, Iryanthera, Myristica,* Virola.

* Represented in the Kew slide collection.

(ii) For Wood Structure

Brochoneura, Cephalosphaera, Coelocaryon, Compsoneura, Dialyanthera, Gymnacranthera, Horsfieldia, Iryanthera, Knema, Myristica, Pycnanthus, Scyphocephalium, Staudtia, Virola.

Literature

(i) *On General Anatomy*

Worsdell **2468.**

(ii) *On Wood Structure*

Benoist **170**, den Berger **179**, **182**, den Berger and Endert **183**, Besson **186**, Brit. Hond. For. Dept. **274**, Burgerstein **310**, Cockrell **434**, Cooper and Record **461**, Garratt, G. A. **746**, **747**, **747A**, Hopkinson **1083**, Howard **1088**, Janssonius **1154**, Jentsch **1171**, Kanehira **1206**, **1209**, Kribs **1283**, Lecomte **1334**, Martin Levigne **1450**, Méniaud **1492**, Normand **1609**, Pearson and Brown **1679**, Pfeiffer, J. Ph. **1713**, Record **1836**, **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**, Riera **1937**, Stone **2202**, Williams **2430**.

228. MONIMIACEAE

(Fig. 275 on p. 1140; Fig. 276 on p. 1148; Fig. 278 on p. 1158)

Summary

(i) General

A tropical and sub-tropical family of shrubs, trees, and a few climbers. They are frequently aromatic owing to material deposited in spherical **secretory cells** with clear or brown contents, situated in the mesophyll of the leaf, and in the axis. Those in the leaf sometimes appear as transparent dots. **Hairs** are exclusively non-glandular, mostly unicellular, but sometimes 2-armed or tufted. Peltate scales also occur in some genera. **Stomata,** confined to the lower surface, are usually ranunculaceous. A **hypoderm** is differentiated below the upper epidermis in nearly all genera. **Crystals** are mostly secreted in the form of small needles. The **cork** arises superficially in the few investigated species. The primary **cortex** frequently becomes sclerosed or contains stone cells.

(ii) Wood

Vessels usually moderately small and mostly solitary, perforation plates usually predominantly scalariform with more than 20 fine bars, sometimes predominantly simple (rarely simple only), the former accompanied by scalariform to opposite intervascular pitting and large scalariform pits to parenchyma, the latter by alternate intervascular pitting and small pits to parenchyma that tend to be opposite; members moderately to very long. **Parenchyma** very variable, ranging from extremely sparse diffuse to numerous uniseriate apotracheal bands, and from occasional cells touching the vessels to broad bands that are in contact with nearly all the vessels. **Rays** (*a*) in the Atherospermoideae, relatively narrow, usually up to 3–4 cells wide, less or more than 1 mm. high, heterogeneous with 1–4 marginal rows, uniseriates moderately numerous, 9–14 rays per mm.; oil cells present in a very few species; (*b*) in the Monimioideae, wide and high, mostly more than 7 cells wide, more than 1, and up to 15 mm. high, heterogeneous with 1–4 marginal rows or composed almost entirely of square and upright cells, uniseriates usually few or absent, usually 1–4 rays per mm. **Fibres** with simple to distinctly bordered pits, septate fibres present in nearly every genus and sometimes predominating; moderately long.

LEAF

Dorsiventral. Leaf margin supported by mechanical tissue in *Peumus boldus* Molina. **Hairs** exclusively non-glandular, mostly unicellular, and often with thickened walls; tending to be tufted in *Daphnandra*, *Doryphora*, *Laurelia*; sometimes 2-armed in species of *Atherosperma*, *Matthaea*, *Mollinedia*. Long tufted hairs on a sclerenchymatous base recorded in *Peumus* and *Siparuna*, and peltate scales (Fig. 278 A) in species of *Conuleum*, *Hortonia*, *Monimia*, *Palmeria*, *Siparuna*. **Epidermis** usually composed of small cells. **Hypoderm,** consisting of 1 or more layers of cells beneath the upper epidermis, very common in all examined species and genera except *Amborella*, *Atherosperma*, *Daphnandra*, *Glossocalyx*, *Matthaea*, *Piptocalyx*, *Siparuna* (pro parte), *Trimenia*. **Stomata** almost exclusively confined to the lower surface, except sometimes in *Siparuna*; usually ranunculaceous but figured by Beauvisage (163) as rubiaceous in *Trimenia*. **Mesophyll** usually including a single or, more rarely, 2 or more layers of palisade cells. Typical palisade tissue sometimes absent from *Amborella*. Very large intercellular spaces present in the spongy tissue. Mesophyll consisting wholly of spongy tissue in species of *Glossocalyx*, *Piptocalyx*, *Trimenia*. **Petiole** (Fig. 276 A–C), in transverse sections through the distal end, exhibiting a shallow crescentic, median vascular strand in *Laurelia novae-zeylandiae* A. Cunn. (Fig. 276 B), *Peumus boldus* Mol. (Fig. 276 C), *Trimenia weinmanniaefolia* Seem (Beauvisage 163), and a similar but slightly dissected strand in *Doryphora sassafras* Endl. (Fig. 276 A). Large, solitary and clustered stone cells present in the petiolar ground-tissue in the last species.

Spherical **secretory cells** (see also under 'Axis'), with clear or brown contents, universally present, frequently appearing as transparent dots in the leaf; generally situated in the mesophyll, but said to occur in the epidermis as well in species of *Conuleum*, *Daphnandra*, *Mollinedia*, *Siparuna*, *Tambourissa*; confined to the hypoderm in *Monimia*. Mucilage cells absent, this character serving to distinguish the Monimiaceae from some of the allied Lauraceae. Vascular bundles of the larger **veins** usually surrounded by a ring of sclerenchyma except in a few species of *Siparuna*. Branches of the sclerenchyma around the veins extend into the mesophyll in a few other species of *Siparuna*. **Crystals,** chiefly in the form of very numerous small

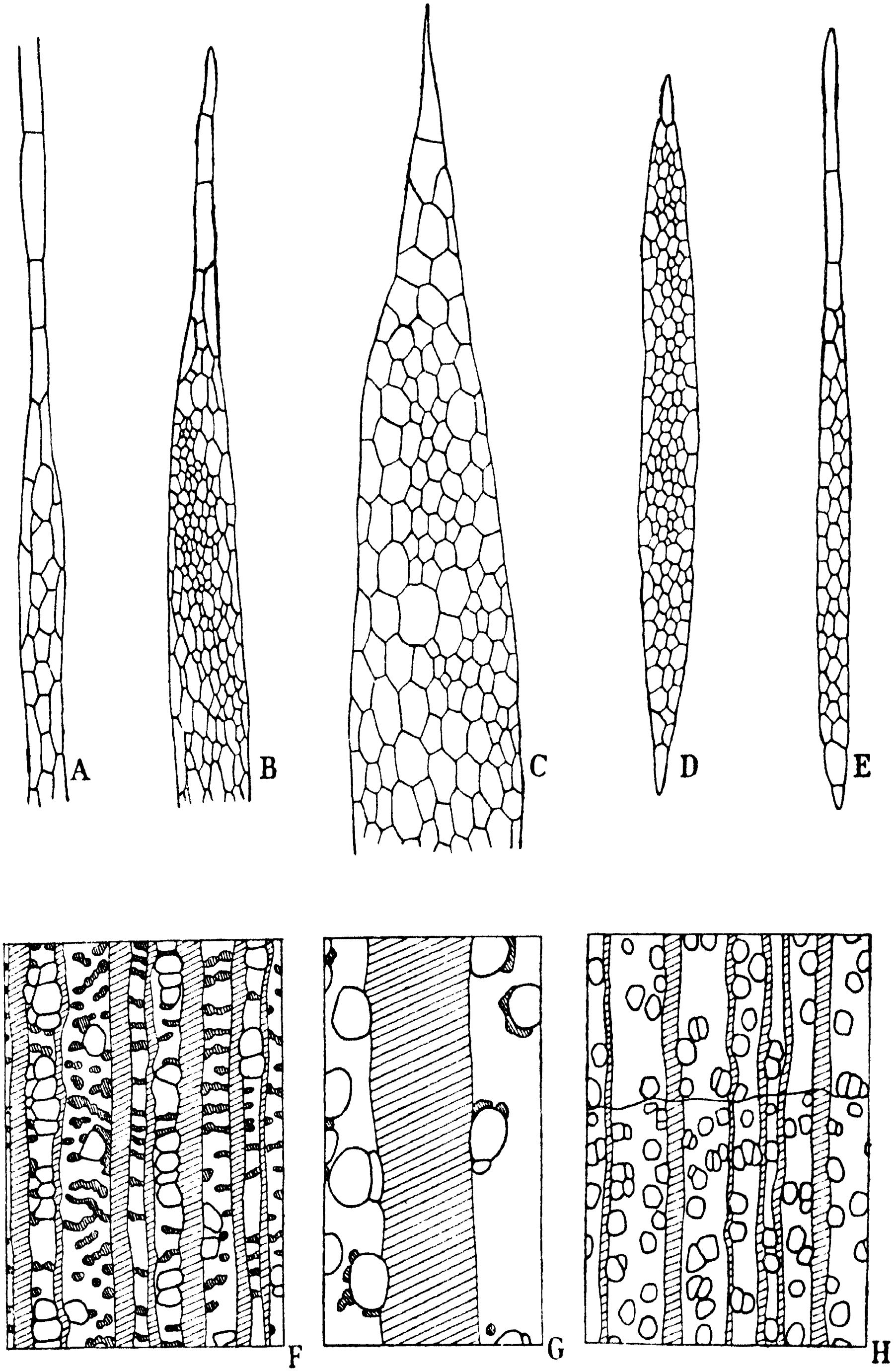


FIG. 275. *MONIMIACEAE*

A, *Siparuna pauciflora* A. DC. B, *Hedycarya angustifolia* A. Cunn. C, *Tambourissa thouvenotii* P. Dang. D, *Daphnandra micrantha* Benth. E, *Doryphora sassafras* Endl. F, *Siparuna pauciflora* (Beurl.) A. DC. G, *Tambourissa thouvenotii* P. Dang. H, *Atherosperma moschatum* Labill.

needles, frequently present throughout the mesophyll. Small cubical crystals and rhombohedra also recorded in the region of the veins.

AXIS

YOUNG STEM (Fig. 276 D, F)

Cork arising superficially in the few examined species of *Doryphora* (Fig. 276 F), *Peumus* (Fig. 276 D) (sometimes fairly deep in the cortex), *Monimia*, *Siparuna*, *Trimenia* (Beauvisage 163). Primary **cortex** well developed, at first consisting of thin-walled or slightly collenchymatous cells, the last type recorded particularly in *Siparuna*; large intercellular spaces present in the cortex of *Laurelia*; becoming sclerosed at an early stage in most genera except *Daphnandra*, *Laurelia*, *Matthaea*, *Peumus*; a ring of stone cells developing in this region in species of *Siparuna*. **Pericycle** usually including a composite and continuous or somewhat interrupted ring of sclerenchyma, partly composed of characteristic stone cells with thin, outer, tangential walls. Pericyclic sclerenchyma consisting only of strands of fibres in many species of *Siparuna* and absent from *Conuleum*. Secondary **phloem** containing fibres in *Conuleum* and rod cells in species of *Atherosperma*, *Conuleum*, *Hedycarya*, *Monimia*, *Peumus*. **Xylem** in the form of a continuous cylinder traversed by narrow rays in *Doryphora sassafras* Endl. (Fig. 276 F) and *Laurelia novae-zeylandiae* A. Cunn., but dissected by broader rays with expanded distal endings in the phloem in *Peumus boldus* Mol. (Fig. 276 D). Vessels with scalariform perforation plates seen in the same species of *Doryphora* and *Laurelia*, but only simple perforations noted in *Peumus* (see also under 'Wood'). **Secretory cells,** similar to those described under 'Leaf', generally present in the primary cortex, phloem, pith, and, more rarely, the medullary rays. **Tannin sacs,** at the margin of the pith and in the phloem, reported to occur in species of *Siparuna*. **Crystals** commonly acicular or in the form of raphides, often in special cells in the unlignified tissues.

WOOD (Fig. 275)

Vessels mostly moderately small (50–100 μ mean tangential diameter), occasionally rather larger, e.g. in *Tambourissa*; apparent tangential pairs due to overlapping ends very common, otherwise mostly solitary, though always with a few small radial multiples; multiples of 4 or more cells common in *Xymalos* and often with long multiples giving a radial pattern in *Siparuna* (Fig. 275 F); mostly 20–75 per sq. mm., fewer in some species of *Bracteanthus*, *Hedycarya*, *Kibara*, and *Tambourissa*; sometimes more than 125 per sq. mm., e.g. in *Atherosperma moschatum* Labill. (2404); Solereder (2158) refers to fine spiral thickening in *Peumus boldus* Molina. Perforation plates simple or scalariform or both, slightly to very oblique; exclusively scalariform, (*a*) with more than 20 fine bars in *Atherosperma* (with up to 100 bars), *Daphnandra*, *Doryphora*, *Kibara*, *Laurelia*, *Matthaea*, *Mollinedia*, *Tambourissa*, and *Trimenia*, and (*b*) with fewer than 20, and often very few, bars in *Hedycarya* and *Xymalos*; both simple and scalariform in *Bracteanthus* (sometimes simple only), *Laurelia*, and *Siparuna*, and simple only in *Peumus*. Garratt (747A) notes that in *Doryphora* 'predominantly scalariform plates are occasionally to frequently replaced at both ends of vessel members by pitted areas, in which the small, but distinctly bordered, pits are mostly opposite and horizontally elongated, with tendency to scalariform arrangement; similarly pitted areas are of rare occurrence in a few of other investigated genera'. Intervascular pitting (*a*) scalariform to opposite, usually with scalariform predominating, in the genera with exclusively scalariform perforation plates, (*b*) alternate and small to rather large in *Bracteanthus*, *Peumus*, and *Siparuna*. Pits to ray and wood parenchyma (*a*) large and radially elongated, usually scalariform, characteristic of the genera with scalariform perforation plates, and (*b*) similar in size and shape to the alternate intervascular pitting in *Bracteanthus*, *Peumus*, and *Siparuna*, but tending to opposite arrangement; commonly unilaterally compound in *Siparuna*, with 6 or more small vessel pits to 1 elongated ray pit (747). Sometimes containing tyloses. Mean member length 0·9–1·5 mm. (measurements representing only genera with scalariform perforation plates). **Parenchyma** usually sparse, sometimes extremely so, e.g. in *Atherosperma*, *Daphnandra*, *Doryphora*, and *Laurelia*; tending to be predominantly apotracheal, but predominantly paratracheal, consisting of a few cells round the vessels in *Kibara*, *Matthaea*, *Mollinedia*, *Peumus*, and *Tambourissa* (Fig. 275 G),[1] and, according to Garratt (747A), with a slight paratracheal tendency in *Hedycarya* and *Tambourissa*; sometimes distinctly paratracheal in *Kibara*; apotracheal parenchyma abundant in *Siparuna* and often in numerous uniseriate bands (Fig. 275 F); abundant, according to Garratt, in *Bracteanthus*, in regular, closely spaced bands 1–6, mostly 2–4, cells wide, in contact with most of the vessels though 'rarely definitely embracing them'. **Rays** (*a*) in the Atherospermoideae, i.e. in the genera *Atherosperma*, *Daphnandra*, *Doryphora*, *Laurelia*, and *Siparuna*, relatively small; mostly up to 3–4 cells wide, but sometimes up to 5 or 6 cells wide, e.g. in *Daphnandra*, *Laurelia*, and *Siparuna*; multiseriate rays from less than 1 mm. high in *Atherosperma* and *Doryphora* to very high in *Siparuna*; uniseriates moderately numerous and composed entirely of upright cells; typically about 9–14 rays per mm.; heterogeneous (Kribs's Type II A), usually with fewer than 4 marginal rows of upright cells; composed almost entirely of square or upright cells in *Siparuna*; without sheath cells except in *Daphnandra*. Garratt (747A) reports occasional oil cells in *Daphnandra micrantha* Benth. and *Doryphora sassafras* Endl. (*b*) In the Monimioideae, i.e. in *Hedycarya*, *Kibara*, *Matthaea*, *Mollinedia*, *Peumus*, and *Xymalos*, typically broad and high, though low in *Peumus* (747A), commonly up to 7–8 cells wide; up to 16 cells in *Tambourissa quadrifida* Sonn., and from 0·14 to over 0·5 mm. wide (747A); not more than 3–4 cells wide in *Trimenia*; Williams (2430) describes the rays of 3 Peruvian species of *Mollinedia* as 3–4 cells wide; multiseriate rays typically more than 1 mm. high, often exceeding 10 mm. in *Mollinedia* (2404); uniseriates typically few and low, but moderately numerous in some species of *Hedycarya*, composed of upright cells; typically about 1–4 rays per mm. in woods with few uniseriates; heterogeneous, the larger rays often composed mainly of square or upright cells with relatively few procumbents, but seldom with more than 4 uniseriate marginal rows of upright cells; almost homogeneous in *Peumus* (533). Crystals reported (747A) to be common in *Matthaea*. **Fibres** with distinctly bordered pits in *Atherosperma*, *Daphnandra* p.p. (2404), *Dory-*

---

[1] No authentic material of *Tambourissa* was available, but the two species examined agreed generally with the description by Perrot (1694).

phora, *Laurelia*, *Matthaea*, *Mollinedia*[1] p.p., and *Xymalos*, tending to be mostly on the radial walls; with simple or indistinctly bordered pits in *Bracteanthus*, *Daphnandra* p.p., *Hedycarya*, *Kibara*, *Monimia* (2158), *Peumus* (747A), *Siparuna*, *Tambourissa*, and *Xymalos* p.p. Some septate fibres present, according to Garratt (747A), in all the genera except *Bracteanthus* and *Siparuna*, and often predominant to exclusive; usually with relatively few septate fibres in the Atherospermoideae. According to Garratt, the septate fibres are simple-pitted, except in *Mollinedia*, 'even in those woods in which non-septate fibres bear distinctly bordered pits; in *Mollinedia* predominant septate fibres appear to bear bordered pits, although the bordered condition is more or less indistinct'. Walls sometimes thick, e.g. in *Doryphora*, *Kibara*, *Siparuna*, *Tambourissa*, and *Xymalos*. Mean length (genera with scalariform perforation plates) 1·6–2·1 mm.

Peumus, according to Dadswell and Record (533), differs from the other members of this family in that 'the vessels have exclusively simple perforations, fine spirals, and alternate pitting; rays nearly homogeneous; wood fibres with simple pits'.

TAXONOMIC NOTES

(i) FROM WOOD STRUCTURE

1. *Internal Classification.* The woods of the Atherospermoideae and Monimioideae can be distinguished from each other by their rays and tend to differ consistently in some other features, particularly if 1 or 2 genera are excepted, e.g. *Bracteanthus*, *Peumus*, and *Siparuna*; these genera do not fit into either tribe. *Bracteanthus* and *Siparuna* have much in common; with regard to *Peumus*, Garratt (747A) concludes that, if it is correctly included in the Monimiaceae, it should at least be placed in a tribe separated from those established by Perkins and Gilg. From an unpublished description (376) the rays of *Trimenia* appear to be more typical of the Atherospermoideae than of the Monimioideae.

2. *Relationship to Other Families.* Owing to the varied wood structure within the family, particular genera can be quoted as indicating resemblance to many other families. Garratt (747A) points out that *Atherosperma*, *Daphnandra*, *Doryphora*, and *Laurelia* are similar to the woods of the Myristicaceae, but 'the closest resemblance appears in some of the investigated species of *Siparuna*'. *Atherosperma*, &c., are also observed to have many features in common with the Magnoliaceae and Schisandraceae. *Bracteanthus* and *Peumus* show the least similarity of any of the genera to the Myristicaceae but the most to the Lauraceae; Garratt also notes that these genera and *Siparuna* have some points of similarity to Annonaceae, Calycanthaceae, and Hernandiaceae, but that the other genera are anatomically quite distinct from these families. It is also suggested that *Peumus* and, to a less extent, *Bracteanthus* and *Siparuna* are related to the Urticaceae.

---

[1] Williams (2430) considers the pits as simple in the Peruvian species that he describes, and Welch (2404) those of *M. huegeliana* Tulasne as indistinctly bordered. There is an unusual lack of agreement between different authors as to the type of pitting characteristic of particular genera in this family; this may be due to actual variation among species, but may possibly be at least partly explained by the difficulty of distinguishing in all cases between the pits of the septate and of the non-septate fibres.

(ii) FROM GENERAL ANATOMY

Beauvisage (163) has discussed the taxonomic position of *Trimenia* from the anatomical standpoint, and rightly concluded that its affinities lie with the Monimiaceae. It is interesting to note, however, that this genus, unlike the other members of the family which have been examined, possesses rubiaceous stomata.

ECONOMIC USES

The timbers of this family are not generally of importance. A few, however, are used locally; particularly some of the Australian species, which furnish wood suitable for turnery of all kinds, including tool and broom handles and clothes-pegs (2404). Among these are Grey or Black Sassafras, *Doryphora sassafras* Endl., Tasmanian Sassafras, *Atherospermum moschatum* Labill., and Yellow Sassafras, *Daphnandra micrantha* Benth. Species of *Laurelia* and *Xymalos* are used to some extent in New Zealand and South Africa respectively for furniture and other purposes.

Boldo leaves, from *Peumus boldus* Molina (syn. *Boldea boldus* (Mol.) Looser), a Chilean shrub, are used in medicine. The greyish-green, ovate, shortly petiolate, coriaceous leaves about 3–8 cm. long and 2–4 cm. wide are characterized by the following microscopical characters. Simple, thick-walled, unicellular hairs, mostly solitary, but sometimes tending to be in stellate groups on the upper surface; stellate hairs made up of unicellular components chiefly on the lower surface; ranunculaceous stomata confined to the lower surface; a 1- to 2-layered hypoderm, composed of thick-walled cells below the upper epidermis; 2 layers of palisade tissue; large, well-developed, sclerenchymatous sheaths surrrounding the vascular bundles; secretory cells, some of which have yellowish contents, more numerous in the spongy mesophyll than in the palisade tissue; lack of calcium oxalate crystals. For further microscopical details see the descriptions by Scala (2019) and Tunman (2289).

The leaves of *Cryptocarya peumus* Nees. (family Lauraceae), which have been substituted for Boldo, do not possess stellate hairs.

The bark of Australian Sassafras (*Doryphora sassafras* Endl.) is stated to possess tonic properties. The fruits of *Laurelia aromatic* Juss. are known as Peruvian nutmegs.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Amborella, Atherosperma, Conuleum, Daphnandra, Doryphora,* Glossocalyx, Hedycarya, Hortonia, Laurelia,* Matthaea, Mollinedia, Monimia, Palmeria, Peumus,* Piptocalyx, Siparuna, Tambourissa, Trimenia, Xymalos.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Atherosperma, Bracteanthus, Daphnandra, Doryphora, Hedycarya, Kibara, Laurelia, Matthaea, Mollinedia, (Monimia), (Peumus), Siparuna, Tambourissa, (Trimenia), Xymalos.

LITERATURE

(i) *On General Anatomy*

Beauvisage 163, Ohtani 1636, Scala 2019, Tunman 2289.

(ii) *On Wood Structure*

Dadswell **525**, Dadswell and Record **533**, Garratt **747**, **747A**, Janssonius **1154**, Perrot **1694**, Record **1851**, Record and Hess **1886**, Tupper **2295**, Welch **2404**, Williams **2430**.

229. LAURACEAE

(FIG. 276 on p. 1148; FIG. 277 on p. 1150)

SUMMARY

(i) GENERAL

Apart from the parasitic genus *Cassytha*, which has a twining habit somewhat similar to that of *Cuscuta* (Convolvulaceae), this tropical and subtropical family consists of shrubs and trees which are frequently aromatic. The **hairs** are very uniform, mostly unicellular, and often thick-walled. The lower **epidermis** of the leaf is commonly papillose. **Hypoderm** beneath the upper epidermis is present throughout *Endiandra*, and recorded in certain species of a few other genera. The **stomata** are rubiaceous, confined to the lower surface, and frequently sunken. The vascular bundles of the **veins** are often vertically transcurrent. **Cork** is usually rather late in developing and arises superficially. The **pericycle** is provided with a continuous or interrupted, but always composite, ring of sclerenchyma. The thickenings of the stone cells in this ring are U-shaped as seen in transverse sections. The secondary **phloem** contains isolated fibres or bundles of fibres. **Secretory cells** containing oil or mucilage occur generally in both leaf and axis, even in the parasitic genus *Cassytha*, but oil cells are to be found in many species from which mucilage cells are absent.

The development of the secretory cells in species of *Cinnamomum* and *Laurus* has been described in detail by Lehmann (1343) and in *Persea* by Leemann (1341).

(ii) WOOD

Vessels mostly medium-sized, occasionally with some multiples of 4 or more cells or with a slight diagonal pattern, perforation plates exclusively simple or with a few sporadic scalariform plates as well, intervascular pitting alternate and typically large, pits to parenchyma typically large and elongated and often almost scalariform, members of medium length. **Parenchyma** paratracheal, typically scanty to vasicentric, occasionally aliform, terminal bands present in a few genera, often containing oil cells. **Rays** usually 2–3 cells wide, but up to 8 cells wide in some species, usually with few uniseriates, weakly heterogeneous to homogeneous, often with oil cells. **Fibres** typically with simple pits, commonly septate, of medium length to moderately short. **Oil** or **mucilage cells** are characteristic of the family, occurring in the wood parenchyma or the rays or, less commonly, in both; seldom entirely absent.

LEAF

Generally dorsiventral, but palisade tissue more strongly developed towards the abaxial than towards the adaxial surface of the leaf in species of *Nectandra*, *Phoebe*, *Silvia*. Considerable mechanical tissue at the **leaf margin** in species of *Cinnamonum* and *Laurus* recorded by Ohtani (1636). **Hairs** mostly unicellular, frequently thick-walled, the lumen sometimes almost obliterated. Differences in hair structure in various Philippine species of *Cinnamomum* described in detail by Santos (1991). **Cuticle** delicately punctate in some species of *Ocotea*; varying in thickness in different species of a single genus from the same habitat, according to Teschner (2242). Cells of the lower **epidermis** papillose in species of *Acrodiclidium*, *Actinodaphne*, *Aniba*, *Beilschmiedia*, *Cinnamomum*, *Cryptocarya*, *Endiandra*, *Endlicheria*, *Litsea*, *Nectandra*, *Persea*, *Phoebe*, *Tetradenia*. Epidermal cells sometimes tall in *Aniba*, *Endlicheria*, *Nectandra*, *Ocotea*, *Persea*, *Phoebe*. Epidermal cells with sinuous anticlinal walls, especially on the upper surface, recorded by Bandulska (130) in modern species of *Aniba*, *Beilschmiedia*, *Cryptocarya*, *Laurus*, *Lindera*, *Neolitsea*, and *Phoebe*, who made comparisons with 'cuticles' of fossilized lauraceous leaves from the Eocene beds at Bournemouth. Epidermis of Philippine species of *Cinnamomum* described by Santos (1991) as composed of polygonal cells with thick, sinuous, anticlinal walls. Marlier-Spirlet (1443) has classified numerous species of *Cinnamomum* in 3 groups which differ in the degree of cutinization, and other minor details, of the upper epidermis. **Stomata** confined to the lower surface; frequently sunken; rubiaceous, but subsidiary cells of depressed stomata not easily recognizable. Guard cells provided with ridge-like processes in species of *Acrodiclidium*, *Aniba*, *Cryptocarya*, *Dicypellium*, *Endlicheria*, *Misanteca*, *Nectandra*, *Ocotea*, *Phoebe*, and probably other genera. Bandulska (130) used details of stomatal structure when attempting to identify fossilized leaves from the Eocene beds at Bournemouth. **Hypoderm,** usually consisting of a single layer, recorded beneath the adaxial surface of the leaf in species of *Aydendron*, *Beilschmiedia*, *Cryptocarya*, *Endiandra* (in all species according to Teschner (2242), occasionally 2-layered in this genus), *Endlicheria*, *Hufelandia* (sometimes beneath both surfaces), *Litsea* (rarely), *Nectandra*, *Ocotea*, *Persea*, *Phoebe*, *Ravensara*. **Mesophyll,** including 1–3 layers of palisade cells, but, according to Teschner (2242), varying in different species even within a single genus; considerable structural uniformity in different species of *Cinnamomum* recorded by Santos (1991), a single layer of palisade tissue being present in each of the 6 species (for list see 'Economic Uses', p. 1154) examined, apart from narrow, secondary layers in *C. burmanni* Blm. and *C. mercadoi* Vid. Individual cells of the palisade layer in some species of *Actinodaphne* and *Ocotea* transformed into elongated stone cells, visible to the naked eye as distinct dots on the surface of the leaf. Sclerified cells, immediately within the lower epidermis, recorded by Dubard and Dop (611) in *Ravensara*.

Spongy parenchyma containing large lacunae filled with stellate tissue, especially in *Persea* and, to a smaller extent, in species of *Acrodiclidium*, *Aniba*, *Cryptocarya*, *Misanteca*, *Systemodaphne*, *Urbanodendron*. **Midrib** of various members of the family said by Ossowski (1642) to be surrounded by a mixed sclerenchymatous sheath similar to that in the pericyclic region of the stem. Stone cells in the sclerenchymatous sheath provided with U-shaped thickenings, the thin outer wall consisting of cellulose. Midrib of *Cinnamomum mercadoi* Vid. and *C. zeylanicum* Nees. described by Santos (1991) as flattened in transverse sections, with fan-shaped groups of collenchyma on the adaxial side; those of *C. burmanni* Blm., *C. cassia* Blm., *C. iners* Reinw., and *C. mindanaense* Elm. slightly convex above and strongly convex below. Medium-sized and small **veins** frequently vertically transcurrent by sclerenchymatous elements; the sclerenchymatous sheath in a few species of *Persea* spreading out beneath the upper epidermis. **Petiole** (Fig. 276 G, H, I, K), in transverse sections through the distal end, exhibiting a shallow, crescentic vascular strand in species of *Cinnamomum*, *Laurus* (Fig. 276 G), *Lindera* (Fig. 276 K) (pro parte), *Persea* (Fig. 276 H), *Umbellularia*; similar but with a more deeply crescentic bundle in *Sassafras*. A shallow arc of separate but closely placed bundles noted in the corresponding position in *Beilschmiedia roxburghiana* Nees. (Fig. 276 I). No accessory bundles noted. Massive stone cells observed in the petiolar ground-tissue of *Cinnamomum zeylanicum* and recorded by Dubard and Dop (611) in the corresponding position in *Ravensara*.

Secretory cells (see also under 'Axis'), containing oil or mucilage, constitute a particularly characteristic feature of the family. (i) Oil cells recorded in the leaf of all investigated species of *Acrodiclidium*, *Alseodaphne*, *Aydendron*, *Beilschmiedia*, *Cinnamomum*, *Cryptocarya*, *Dehaasia*, *Dicypellium*, *Endiandra*, *Laurus*, *Lindera*, *Litsea*, *Machilus*, *Mespilodaphne*, *Nectandra*, *Ocotea*, *Persea*, *Phoebe*, *Sassafras*, *Umbellularia*. Oil cells generally spherical, with suberized walls and yellowish contents; frequently giving rise to transparent dots in the leaf; situated in the palisade or spongy tissue, and rarely, e.g. in *Umbellularia californica* Nutt., in the lower epidermis as well. (ii) Mucilage cells recorded in certain species of *Acrodiclidium*, *Actinodaphne*, *Aydendron*, *Beilschmiedia*, *Dehaasia*, *Linderia*, *Litsea*, *Machilus*, *Mespilodaphne*, *Nectandra*, *Ocotea*, *Persea*, *Phoebe*, *Sassafras*. Mucilage cells, similar in shape to the oil cells described above, usually confined to the palisade tissue, but also occurring in other parts of the mesophyll as well. Secretory cells in fossilized lauraceous leaves from the Eocene beds at Bournemouth described by Bandulska (130). **Crystals** mostly in the form of small needles or spindles. 'Tablet-shaped', octagonal, and small acicular crystals recorded by Ossowski (1642) in the stone cells of the sclerenchymatous sheath around the midrib in a few genera. Clusters and solitary crystals not recorded.

AXIS

YOUNG STEM (Fig. 276 J, L)

Structure very uniform apart from the parasitic *Cassytha* described separately below (p. 1152). The features of the other members of the family are as follows.

Cork not formed until a relatively late stage; often arising in the epidermis or outer part of the cortex, but pericyclic cork said to occur in *Cinnamomum zeylanicum* Nees. Cork cells thin-walled in species of *Litsea*, *Persea*, *Sassafras*; with inner tangential walls sclerosed in species of *Cinnamomum*, *Dehaasia*, *Dicypellium*, *Litsea*, *Oreodaphne*. A secondary ring of stone cells reported to arise in the phelloderm in species of *Actinodaphne*, *Cryptocarya*, *Dehaasia*, *Litsea*, *Mespilodaphne*. Primary **cortex** of relatively old branches sometimes containing stone cells.

Pericycle characterized by isolated strands of fibres interspersed with stone cells to form a continuous or locally interrupted ring. Some of the stone cells usually provided with thin outer tangential walls, but sclerosed on the inner tangential and radial walls. Pericyclic sclerenchyma rings of the above type recorded in species of *Acrodiclidium*, *Beilschmiedia*, *Cinnamomum*,

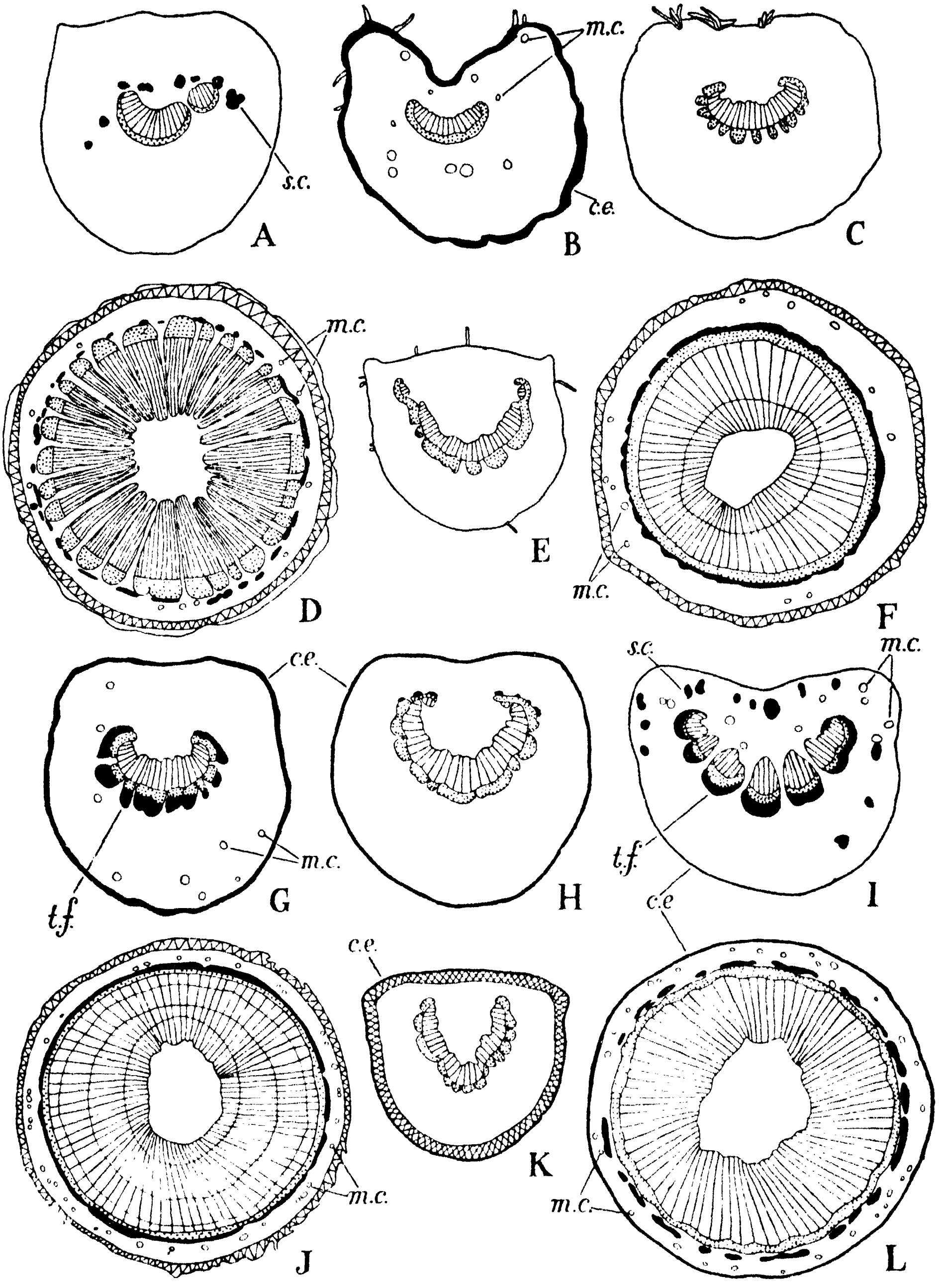


FIG. 276. *MONIMIACEAE*, A–D and F; *LAURACEAE*, E and G–L

A. *Doryph*

C,

(Sa

Pe

×

(sy

Stem × 16.

c.e. Cutinized epidermis. *m.c.* Mucilage cells. *s.c.* Stone cells. *t.f.* Thin-walled fibres.

Cryptocarya, *Dicypellium*, *Endiandra*, *Endlicheria*, *Laurus*, *Lindera*, *Litsea*, *Nectandra*, *Ocotea*, *Persea*, *Phoebe*, *Sassafras*. Secondary **phloem** usually containing a few spindle-shaped fibres with narrow lumina, but fibres sometimes aggregated into bundles in *Acrodiclidium*, *Beilschmiedia*, *Ocotea*. Stone cells similar to those of the pericycle sometimes accompany the fibres in the secondary phloem, particularly in species of *Cryptocarya* and *Litsea*.

Xylem in the form of a continuous cylinder traversed by narrow rays in all of the species examined at Kew; relatively broad rays occur in certain genera (see under 'Wood', below). Vessels usually with simple perforations; scalariform plates occasional. Peripheral part of the **pith,** in a few species examined at Kew, consisting of amyliferous cells with thicker walls than those of the central part. Groups of stone cells sometimes present in the pith, e.g. in species of *Beilschmiedia* and *Ravensara*.

Secretory cells, containing oil or mucilage, present in the primary cortex, phloem, wood, and pith of the axis. (i) Oil cells in the primary cortex and pith approximately isodiametric, but those in the phloem vertically elongated; recorded in the young stem of species of *Acrodiclidium*, *Aydendron*, *Beilschmiedia*, *Cinnamomum*, *Cryptocarya*, *Dicypellium*, *Laurus*, *Litsea*, *Nectandra*, *Oreodaphne*, *Persea*, *Sassafras*, *Umbellularia*. (ii) Mucilage cells, usually vertically elongated, most frequent in the phloem (especially in Cinnamon and other barks (see 'Economic Uses', p. 1153)), but also recorded in the primary cortex and wood. Cells with unidentified but probably tanniniferous contents common and often abundant, particularly in the cortex and phloem, e.g. in species of *Beilschmiedia*, *Cinnamomum*, *Laurus*, *Persea* examined at Kew. **Crystals** common in the unlignified tissues, mostly acicular or spindle-shaped; solitary prisms noted, e.g. in *Beilschmiedia*.

WOOD (Fig. 277 D–F and H–O)

Vessels mostly medium-sized (100–200 μ mean tangential diameter), but sometimes small (less than 100 μ), e.g. in species of *Benzoin*, *Laurus*, and *Lindera*; solitary and in numerous small multiples; multiples of 4 or more cells sometimes moderately common, e.g. in some species of *Alseodaphne*, *Aniba*, *Cryptocarya*, *Eusideroxylon*, and *Laurus*, and sometimes with a tendency to loose oblique rows, e.g. in *Lindera* and *Persea*; 3–40, mostly 5–12, per sq. mm., fewer than 5 per sq. mm. in some species of *Beilschmiedia*, *Cinnamomum*, *Cryptocarya*, *Hypodaphnis*, *Licaria*, and *Tylostemon*. Sometimes ring-porous in *Sassafras* (1206). Perforations typically simple, but sporadic scalariform plates are of moderately common occurrence, particularly in the Persoideae; such plates usually with few bars but with many in *Persea* (1886); according to Knoblauch, as quoted by Solereder, the perforation plates are entirely scalariform in *Hufelandia pendula* Nees., though this is not the case in material examined by the author. Intervascular pitting alternate, typically large, but occasionally small, e.g. in *Ocotea rodiaei* Mez and *Lindera* spp., though not in material of *L. bifaria* Hosseus examined by the author; occasionally striated owing to coalescent apertures, e.g. in *Laurus* and *Umbellularia*; Solereder refers to spiral striation in *Camphora* and '*Tetranthera*'; pits to ray and wood parenchyma typically including many large, elongated and simple or only partially bordered pits, often almost scalariform (Fig. 277 I), and sometimes unilaterally compound (Fig. 277 K), but with only small round

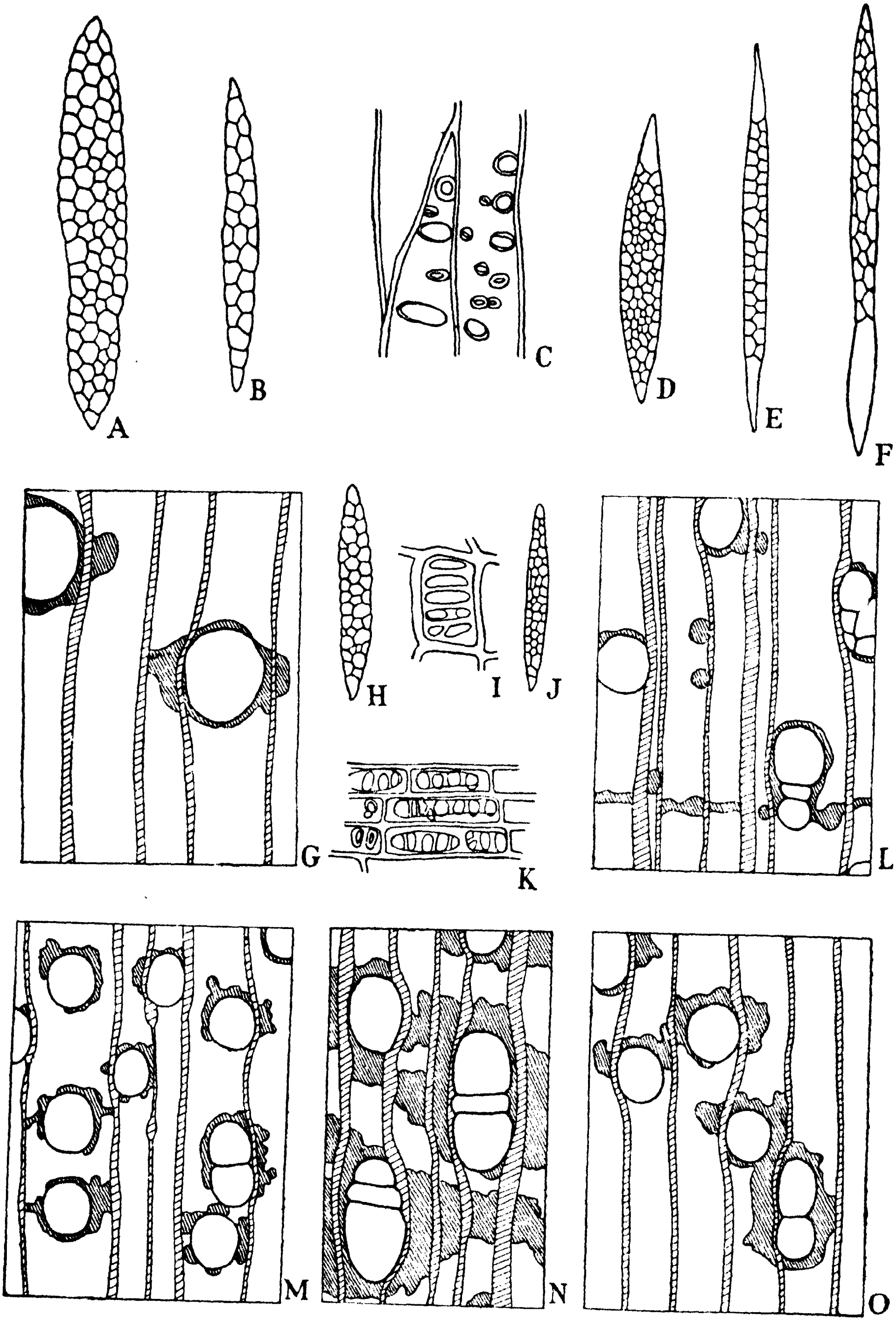


FIG. 277. *HERNANDIACEAE*, A–C and G; *LAURACEAE*, D–F and H–O
A, *Gyrocarpus jacquini* Roxb. B, *Hernandia guianensis* Aubl. C, *H. guianensis* Aubl. Vessel-parenchyma pitting. D, *Beilschmiedia roxburghiana* Nees. E, *Aiouea densiflora* Nees. F, *Cinnamomum*

zwageri Teijsm. et Binn. O, *Ocotea rodiaei* Mez. C, I, and K × 140.

pits similar to the intervascular pitting in *Hypodaphnis zenkeri* Stapf, *Laurus nobilis* L., *Lindera erythrocarpa* Makino, *Neolitsea acuta-trinerva* (Hayata) Kanehira et Sasaki, and *Ocotea rodiaei*. According to Bailey (78) the sieve-like structures reported by Janssonius (1154) are not true vestured pits. Tyloses common, sclerotic in *Eusideroxylon zwageri* Teijsm. et Binn. and *Ocotea rodiaei* and, according to Record and Hess (1893), in some species of *Aniba* and *Licaria*. Mean member length 0·35–0·8 mm. **Parenchyma** paratracheal, typically as an irregular and often incomplete sheath round each vessel, sometimes tending to be aliform, e.g. in *Beilschmiedia*, *Cryptocarya*, *Eusideroxylon*, *Hypodaphnis*, *Lindera*, *Silvia*, and *Tylostemon*, and occasionally locally confluent; sometimes very abundant in broad irregular bands in *Eusideroxylon zwageri* (Fig. 277 N); irregularly spaced bands that appear to be terminal present in some species of *Beilschmiedia*, *Cryptocarya*, *Endiandra*, *Hypodaphnis*, *Lindera* (1154), *Ravensara*, *Silvia*, and *Tylostemon*. Most authors refer also to diffuse parenchyma, but, though individual strands separated from the irregular sheaths round the vessels and solitary oil cells may appear to be scattered among the fibres (see note at end of description), it appears to be somewhat misleading to classify these as diffuse. Strands usually of 2–4 cells. Tendency to be storied observed in *Silvia duckei* Sampaio and distinct stories reported (1819) in 2 species of *Cryptocarya* from Madagascar. Oil cells (see also at end of description) present in more than half the species examined, often very abundant and sometimes very large, e.g. in *Tylostemon mannii* Stapf. **Rays** typically 2–3 cells wide and up to 4–8 cells wide in some species or specimens of *Beilschmiedia*, *Cinnamomum*, *Cryptocarya*, *Endiandra*, *Eusideroxylon*, *Persea*, and *Ravensara*; less than 1 mm. high; uniseriates typically very few and low and composed of mixed upright and procumbent cells, but more numerous and composed entirely of upright cells in some species of *Beilschmiedia*, *Cryptocarya*, and *Tylostemon*; occasional 'aggregate' rays noted by Dadswell and Eckersley (526) in *Cryptocarya glaucescens* R. Br. and *C. corrugata* White et Francis, such rays, according to Francis (706), associated with the deep indentations characteristic of the mature stem; 4–11, mostly 5–7, rays per mm.; typically rather weakly heterogeneous (Kribs's Type II B), with 1 marginal row of square cells, sometimes homogeneous, e.g. in *Hypodaphnis zenkeri* and *Umbellularia californica* Nutt. Janssonius (1154) and Dadswell and Eckersley (526) refer to occasional sheath cells in some species. Cells often with dark solid contents; crystals not observed. Occasionally with a distinct tendency to arrangement in echelon, particularly in some species of *Beilschmiedia* and in *Silvia duckei*. Commonly containing oil cells. Gonggrijp (794) notes the presence of silica in *Endiandra* and *Litsea*. **Fibres** typically with simple pits that are more numerous in the radial than in the tangential walls, but the pits occasionally with small, rather indistinct borders in some of the species lacking septate fibres, e.g. some species of *Actinodaphne*, *Beilschmiedia*, *Endiandra*, and *Ocotea rodiaei*. Septate in *Acrodiclidium* p.p., *Actinodaphne* p.p., *Aiouea*, *Alseodaphne*, *Aniba*, *Cinnamomum* p.p., *Dehaasia*, *Dicypellium*, *Endlicheria*, *Licaria*, *Lindera* (observed in 1 species only), *Litsea* p.p., *Machilus*, *Mespilodaphne*, *Misanteca*, *Ocotea* p.p., *Oreodaphne*, *Persea*, *Phoebe*, *Pleurothyrium*, *Sassafridium*, *Silvia*, and *Umbellularia*; occasional septate fibres may occur in some of the other genera; for example, Kanehira (1206) notes that in *Tetradenia* (*Neolitsea*?)

the fibres are 'sometimes septate' in 1 of the 3 species he describes. Septate fibres are not limited to the neighbourhood of the vessels, as in the Myristicaceae. Walls usually moderately thick and sometimes very thick, frequently gelatinous. Mean length 0·7–1·6, mostly 1·0–1·4 mm. **Vasicentric tracheids** recorded by Janssonius (1154) in *Phoebe declinata* Nees., *Iteadaphne confusa* Bl., and several species of *Litsea*.

Oil or **mucilage cells** are characteristic of the woods of this family, occurring usually in either the wood parenchyma or the rays and relatively rarely in both, e.g. in some species of *Acrodiclidium*, *Aiouea*, *Cinnamomum*, *Cryptocarya*, *Persea*, and *Phoebe*; more commonly present in the wood parenchyma than in the rays and then occurring round the vessels and in the bands of parenchyma, if these are present. Isolated cells sometimes appear to be scattered among the fibres in transverse sections (Fig. 277 L), but at least some of these are due to the presence on the margins of the rays of occasional high oil cells that may project into a transverse section that misses the rest of the ray. According to Janssonius (1148) oil and mucilage cells are indistinguishable except by their contents and are to some extent interchangeable; he found oil cells to be more numerous than mucilage cells, except in *Cinnamomum iners* Reinw., *C. javanicum* Bl., and *C. burmanni* Bl.; to these may be added *Machilus thunbergii* Sieb. et Zucc., the source of the Chinese 'Pau Hoi' (1795). Oil or mucilage cells not observed or very rare in some species or specimens of *Actinodaphne*, *Beilschmiedia*, *Cryptocarya* (526), *Endiandra* (526), *Hypodaphne*, *Lindera*, *Neolitsea*, *Ocotea rodiaei*, and *Oreodaphne*, and Kanehira (1206) notes the following genera of which individual specimens may or may not possess these cells, *Actinodaphne*, *Cryptocarya konishii* Hay., *Lindera*, *Litsea*, *Machilus*, *Phoebe*, and *Tetradenia*.

ROOT

Phloem in the root of *Sassafras variifolium* (Salisb.) O. Kunze (syn. *S. officinale* Nees.) described by Holm (1032) as including numerous, isolated fibres.

CASSYTHA

SUMMARY

Cassytha includes very much reduced plants with a habit somewhat similar to that of *Cuscuta*. They are generally described as parasites, but the presence of chlorenchyma in the axis indicates that they must be at least partly autotrophic. The following particulars concerning *Cassytha filiformis* Jacquin (*C. americana* Nees.) have been recorded partly by Solereder and partly in the more recent paper by Kienholz (1236).

STEM

Epidermis composed of heavily cutinized, rectangular cells. **Stomata** arranged in rows, with their pores at right angles to the axis; rubiaceous; deeply sunken, and with a heavy cuticular ridge forming an outer vestibule to the narrow stomatal pore. Outer part of the **cortex** composed of 1 or 2 layers of small, rounded cells. **Endodermis** not differentiated. **Phloem** in the form of strands situated in furrows in the outer periphery of the xylem. **Xylem** in the form of a continuous cylinder, bounded internally by protoxylem groups extending into the pith. Vessels in the inner part of the secondary wood 120 μ or more in diameter, and much larger than those in the denser peripheral part; lateral pits large, circular, bordered; perforations simple. A ring of separate vascular bundles, sometimes consisting wholly of phloem, recorded by Solereder in the hypocotyl and young axis. Acicular **crystals** present in the cortex.

TAXONOMIC NOTES

The Lauraceae is a remarkably uniform family throughout in its wood anatomy, and though some individual species, such as *Ocotea rodiaei* Mez, can be comparatively easily distinguished, the genera are by no means sharply defined.

Dadswell and Eckersley (526) distinguish the Australian woods of the Persoideae (as represented by *Cinnamomum*, *Litsea*, and *Persea*) from those of the Lauroideae (as represented by *Beilschmiedia*, *Cryptocarya*, and *Endiandra*) largely by means of the presence of concentric bands (terminal?) of parenchyma in the latter and their absence from the Persoideae; the Persoideae, it is claimed, are also distinguished by the occurrence of occasional scalariform perforation plates and common gelatinous fibres.

Janssonius (1154) makes a similar parenchyma distinction to divide the Javanese species into 2 groups, which correspond approximately with the Lauroideae and Persoideae; thus group 1 includes *Beilschmiedia*, *Cryptocarya*, *Endiandra*, and *Lindera* p.p. of the Lauroideae, and group 2 includes *Actinodaphne*, *Cinnamomum*, *Dehaasia*, *Litsea*, *Machilus*, and *Nothaphoebe* of the Persoideae together with *Iteadaphne* and some species of *Lindera*, both belonging to the Lauroideae. From descriptions by Kanehira (1206) and others it appears that most species of *Lindera* would fall into group 2. The author has observed regular and distinct terminal bands in *Hypodaphnis*, *Ravensara*, *Silvia*, and *Tylostemon*, and occasional fine bands in some species of *Acrodiclidium*, *Aiouea*, and *Aniba*, but not in *Laurus nobilis* L.

Garratt (747) notes an outstanding similarity to the Myristicaceae, giving as characters of the secondary xylem common to both families the nature of the intervascular and vessel-ray pitting, the type and size (width) of ray, and the general distribution and arrangement of the wood parenchyma (with some exceptions); septate fibres and oil cells also occur in both families. Garratt notes only one major difference, the type of pitting in the fibres.

In another paper (747A) Garratt points out that the woods of the Lauraceae and the Monimiaceae have a number of features in common, the most similar genera of the Monimiaceae being *Bracteanthus* and *Peumus*, though oil cells are lacking from these genera and the type of parenchyma is different.

ECONOMIC USES

Edible fruits derived from this family include the Avocado Pear (*Persea gratissima* Gaertn.), native of Tropical America, but extensively cultivated in other regions; spice consisting of the unripe fruits of *Cinnamomum cassia* Bl.; fruits of *Cryptocarya peumus* Nees. which are eaten in Chile. The leaves of Sweet Bay (*Laurus nobilis* Linn.) are used for flavouring and also yield an oil which is valued in perfumery. Ossowski (1642) has shown how the U-shaped stone cells from the midrib of *L. nobilis* are of considerable diagnostic value even when the leaves are powdered. Camphor is obtained in the Far East by distilling the wood of *Cinnamomum camphora* Nees. et Eberm.

Cinnamon is obtained from the bark of *Cinnamomum zeylanicum* Nees., chiefly in Ceylon and Burma, but also cultivated in other warm countries. It is used in medicine and perfumery and is one of the oldest known spices. The commercial bark occurs in the form of closely packed quills about 1 m. long, 16 mm. wide, and up to about 1·2 mm. thick. The cork is usually removed, but small patches sometimes remain on the dull, yellowish-brown, outer surface which shows wavy lines. There are also faint longitudinal striations on the inner surface. Microscopical characters of the bark of *C. zeylanicum* include secretory cells in the phelloderm containing yellowish oil or mucilage; abundant, large, thick-walled, pitted, isodiametric or tangentially elongated stone cells, sometimes containing starch grains; in the phloem, isolated or short tangential rows of strongly thickened fibres, usually less than 30 μ in diameter and mostly rectangular in transverse section; medullary rays, generally 2 cells wide; acicular crystals of calcium oxalate in some of the cells of the medullary rays and phloem. According to Santos (1991) the crystals are usually clinorhombic or prismatic in *C. zeylanicum*.

Santos (1991) has made a valuable comparison of the barks of *Cinnamomum burmanni* Blm., *C. cassia* Blm., *C. iners* Reinw., *C. mercadoi* Vid., *C. mindanaense* Elm., and *C. zeylanicum* Nees. Noteworthy points recorded include the following. Stone cells (in the phelloderm) form a more or less complete ring in *C. zeylanicum*; a somewhat continuous ring in *C. burmanni* and *C. mindanaense*; a very much interrupted ring in *C. cassia*, *C. iners*, and *C. mercadoi*. Individual stone cells very large, with thick walls in *C. mercadoi* and *C. zeylanicum*; thinner, but distinctly thickened on one side in *C. burmanni*, *C. cassia*, *C. iners*, and *C. mindanaense*. Phloem fibres present in all of the above species except *C. burmanni* and *C. mindanaense* where they are absent or infrequent. Crystals present in the form of raphides in the unlignified tissues in *C. cassia* and *C. mercadoi*; clinorhombic or prismatic in *C. zeylanicum*; clinorhombic or fusiform in *C. iners*; large, prismatic or cubical in *C. burmanni* and *C. mindanaense*. Rays 1–4 or more cells wide in *C. burmanni* and *C. mindanaense*; 1–2 cells wide in the other 4 species.

Birnstiel's (200) thesis on the structure of cinnamon barks deals with 20 species. He showed that these can be divided into 2 main groups on the basis of their anatomical structure. In the first, which includes species from the Malay Peninsula, India, and the foot of the Himalayas, the stone cells occur as 'islands' embedded in the parenchyma of the secondary cortex. In the second group, consisting of species from the sub-tropical regions of Japan and the Himalayas, the greater part of the secondary cortex is composed of pitted, sclerosed cells. Another difference noted by Birnstiel was that tangential rows of phloem fibres are numerous in the first group of species but absent from the second. The 2 sets of species can also be distinguished by their developmental anatomy.

Sassafras bark, obtained in the Eastern U.S.A. from the roots of *Sassafras variifolium* (Salisb.) O. Kunze (syn. *S. officinale* Nees. et Eberm.), is used to a limited extent in medicine. The anatomical features include abundant oil and occasional mucilage cells; rounded starch grains 3–30 μ in diameter in the parenchymatous tissues; isolated, yellowish, thick-walled phloem fibres about 25 μ in diameter; small, acicular crystals in some of the parenchymatous cells. The root and pith from the stem of *Sassafras variifolium* are also occasionally used in medicine.

The botanical source of Coto bark (from Bolivia and Colombia), which was at one time used in medicine, is obscure, but, according to Kostermans (1269), it is the product of *Aniba coto* (Rusby) Kostermans (syn. *Nectandra coto* Rusby). Paracoto bark, also an article of commerce, is obtained from *Aniba pseudo-coto* (Rusby) Kostermans (syn. *Ocotea pseudo-coto* Rusby).

This family is the source of many useful timbers; indeed, Record and Hess (1886) state that 'the woods of all the trees are suitable for industrial purposes, but comparatively few are known to commerce'. The best-known timbers are Greenheart, *Ocotea rodiaei* (Rob. Schomb.) Mez, from British Guiana, Billian, *Eusideroxylon zwageri* T. et B., from Borneo and Sumatra, Camphor Wood, *Cinnamomum camphora* Nees., from eastern Asia and Formosa, and Stinkwood, *Ocotea bullata* E. Mey., from South Africa.

The mucilaginous extract obtained from shavings of Pau Hoi, *Machilus* sp., is used by Chinese women to bandoline their hair, and an essence used in the perfume industry is obtained from the Bois de Rose, *Aniba roseodora* Ducke, of French Guiana (1886).

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Acrodiclidium, Actinodaphne, Alseodaphne, Aniba, Aydendron, Beilschmiedia,* Cassytha, Cinnamomum,* Cryptocarya, Dehaasia, Dicypellium, Endiandra, Endlicheria, Hufelandia, Laurus,* Lindera,* Litsea, Machilus, Mespilodaphne, Misanteca, Nectandra, Neolitsea, Ocotea, Oreodaphne, Persea,* Phoebe, Ravensara, Sassafras,* Silvia, Systemodaphne, Tetradenia, Umbellularia,* Urbanodendron.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Acrodiclidium, Actinodaphne, Aiouea, Alseodaphne, Anaueria, Aniba, Beilschmiedia, Cinnamomum, Cryptocarya, Daphnidium, Dehaasia, Dicypellium, Endiandra, Endlicheria, Eusideroxylon, Hufelandia, Hypodaphnis, (Iteadaphne), Laurus, Licaria, Lindera, Litsea, Machilus, Mespilodaphne, Misanteca, Nectandra, Neolitsea, Nothaphoebe, Ocotea, Oreodaphne, Persea, Phoebe, Pleurothyrium, Ravensara, Sassafras, Sassafridium, Silvia, Tylostemon, Umbellularia.

LITERATURE

(i) *On General Anatomy*

Allen **19**, **20**, Ballard **115**, Bandulska **130**, Birnstiel **200**, Dubard and Dop **611**, Francis **708**, Holm **1032**, Kienholz **1236**, Kostermans **1269**, Leemann **1341**, Lehmann **1343**, Marlier-Spirlet **1443**, Ohtani **1636**, Ossowski **1642**, Santos **1991**, Scala **2021**, Teschner **2242**.

(ii) *On Wood Structure*

Bailey **78**, Beekman **167**, Benoist **170**, den Berger *et al.* **179**, **182**, **183**, Besson **186**, Bournot **246**, Brit. Hon. For. Dept. **274**, Brown, F. B. H. **282**, Brown, H. P. and Panshin **288**, **289**, Burgerstein **312**, Chalk *et al.* **364**, Cooper and Record **461**, Dadswell **525**, Dadswell and Eckersley **526**, Dadswell and Record **533**, Desch **574**, Fanshawe **2519**, Foxworthy **705**, Francis **706**, Garratt **744**, **747**, **747A**, Gonggrijp **794**, Greguss **2522**, Howard **1088**, Janssonius **1147, 1148, 1149, 1154,** Jay **1158,** Jolly **1188,** Kanehira **1206, 1209, 1210, 1211,** Kribs **1283,** Lecomte **1334,** Martin-Levigne **1450,** Mell and Brush **1487,** Méniaud **1492,** Milanez **1517,** Pearson and Brown **1679,** Pereira **1687,** Pfeiffer, J. Ph. **1713,** Record **1783, 1790, 1795, 1818, 1819, 1824, 1825, 1843, 1853,** Record and Hess **1886, 1893,** Record and Mell **1894,** Schmieg **2041,** Scott **2075,** Stone **2202, 2207,** Tang **2231,** Tupper **2296,** Wallis **2348,** Welch **2405,** Williams **2430,** Yamabayashi **2478.**

230. GOMORTEGACEAE

SUMMARY

The sole member of this family is *Gomortega nitida* Ruiz. et Pav., a tree which occurs in Chile. It agrees with the Monimiaceae and Lauraceae in possessing **secretory cells,** whilst the composite ring of sclerenchyma in the **pericycle** of the axis includes stone cells with U-shaped thickenings. The **xylem** is characterized by vessels with scalariform perforation plates and wood fibres with bordered pits.

LEAF

Dorsiventral. **Hairs** not recorded. **Epidermis** composed of cells with straight anticlinal walls. **Stomata** confined to the lower surface; rubiaceous, but subsidiary cells sometimes becoming secondarily divided by a wall at right angles to the pore. A **hypoderm** consisting of 1 or 2 layers of large, thick-walled cells, present beneath the upper epidermis. **Mesophyll** composed of several layers of palisade tissue, and spongy parenchyma with well-developed intercellular spaces. Vascular bundles of the **veins** accompanied by sheaths of sclerenchyma. Spherical **secretory cells,** with yellow, resinous contents, present in all parts of the mesophyll and hypoderm. **Crystals** secreted in the form of small needles or prisms, chiefly in the neighbourhood of the veins.

AXIS

YOUNG STEM

Pericycle containing a composite and fairly continuous ring of sclerenchyma composed of strands of fibres and stone cells, the latter frequently with U-shaped thickenings. **Xylem,** according to Solereder, including vessels up to 30 μ in diameter, provided with scalariform perforation plates usually having numerous bars, the vessel-ray pits being large and simple; scanty wood parenchyma; narrow, heterogeneous rays; wood fibres with bordered pits. Spherical **secretory cells,** similar to those in the leaf, present in the primary cortex and pith; vertically elongated secretory cells also occur in the phloem. **Crystals** resembling those in the leaf, but infrequent; recorded particularly in portions of the medullary rays traversing the phloem.

TAXONOMIC NOTES

As pointed out by Garratt (747A), the wood structure is so inadequately known that it affords little evidence concerning the taxonomic affinities of the family. The same is also true of the general anatomy. *Gomortega* was included by Bentham and Hooker amongst the Lauraceae, whilst Hutchinson treats it as a monotypic family within the Laurales. The occurrence of secretory cells in all parts of the plant, and of scalariform perforation plates to the vessels in the xylem appear to confirm its affinity with the Lauraceae. The fact that the ground-tissue of the wood is made up of fibres with distinctly bordered pits serves to distinguish the Gomortegaceae from most of the Lauraceae, for the wood fibres in the last of these families are usually provided with small, simple pits. It is noteworthy that the woods of the Canellaceae, which are otherwise very much like those of the Lauraceae, resemble *Gomortega* in having the ground-tissue composed of fibres with conspicuously bordered pits. The possibility of affinities between the Gomortegaceae and Canellaceae seems, therefore, to be worthy of further investigation.

GENUS DESCRIBED

Gomortega.

LITERATURE

On Wood Structure
Garratt **747A**

231. HERNANDIACEAE

(FIG. 277 on p. 1150; FIG. 278 on p. 1158)

SUMMARY

(i) GENERAL

A tropical family consisting mostly of shrubs and small trees, although some species are scandent. Like the Lauraceae they are characterized especially by **secretory cells,** which usually contain oil or, less frequently, mucilage, and occur in both leaf and axis. **Stomata** are confined to the lower surface of the dorsiventral leaf, and ranunculaceous and rubiaceous types have been recorded in different genera. **Crystals** are secreted especially in the form of small needles, which occur very widely in the family. In a few species they are accompanied by small octahedra. **Cystoliths** are also to be found in *Gyrocarpus* and *Sparattanthelium.*

(ii) WOOD

Vessels large and mostly solitary, perforations simple, intervascular pitting alternate and large, pits to parenchyma often large, members of medium length to moderately short. **Parenchyma** paratracheal, aliform to confluent and occasionally terminal, oil cells sometimes present. **Rays** up to 3–5 cells wide, with very few to moderately numerous uniseriates, homogeneous. **Fibres** with numerous simple pits, very rarely septate, of medium length.

LEAF

Mostly dorsiventral. **Hairs** nearly always unicellular, usually sclerenchymatous, occasionally bracket-shaped. Glands with unicellular stalks and bicellular heads said to be confined to *Illigera.* Cells of the lower **epidermis** in the somewhat anomalous *Illigera obtusa* Meissn. produced into coronulate papillae connected to one another by ridges of cellulose. Certain cells of the upper epidermis horizontally septate in species of *Sparattanthelium.* **Stomata** confined to the lower surface; ranunculaceous in *Gyrocarpus* and *Sparattanthelium*, but rubiaceous in *Hernandia* and in *Illigera* with the exception of

I. obtusa. **Hypoderm** of 1 or 2 layers recorded beneath the adaxial surface of the leaf in species of *Gyrocarpus* and *Illigera.* **Mesophyll** generally including a single layer of palisade tissue, but 2 layers reported by Kienholz (1236) in *Hernandia ovigera* Linn. Vascular bundles of the **veins** generally accompanied by sclerenchyma in *Hernandia, Illigera,* and *Sparattanthelium,* but perivascular sclerenchyma said by Kienholz (1236) to be absent from *Hernandia ovigera.* Small acicular **crystals** generally occur in all parts of the leaf and sometimes in the axis as well; occasionally accompanied by small octahedra (Fig. 278 B). Large solitary crystals recorded only in the anomalous *Illigera obtusa.* **Cystoliths** (Fig. 278 B) present particularly in the epidermis of *Gyrocarpus* and *Sparattanthelium,* but also occurring in other parts of the leaf as well in the same 2 genera. Cystoliths spherical in *Gyrocarpus,* but exhibiting a radiately branched structure in *Sparattanthelium;* sometimes present in the axis as well as in the leaf of *Gyrocarpus.* **Secretory cells** with oily contents occur in the leaf of all investigated members of the family, and similar cells containing mucilage in *Hernandia.*

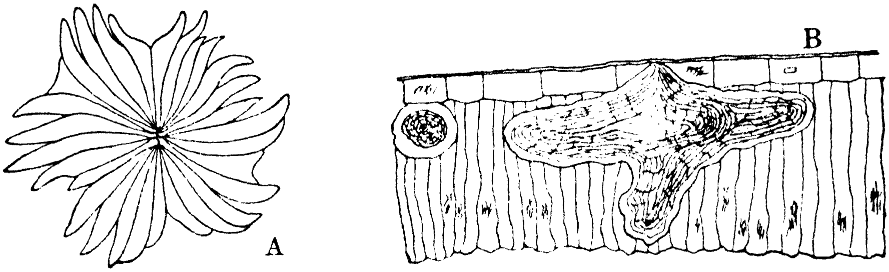


FIG. 278. *MONIMIACEAE,* A; *HERNANDIACEAE,* B

A, Peltate hair of *Siparuna cristata* A. DC. B, Transverse section through the upper portion of the lamina of the leaf of *Sparattanthelium botocudorum* Mart.—A, after O. Bachmann. B, by Solereder.

AXIS

YOUNG STEM

Cork arising in the outer part of the primary cortex in species of *Gyrocarpus* and *Hernandia*; composed of cells with wide lumina and thin walls in the same 2 genera. Outer part of the primary **cortex** frequently collenchymatous; inner part composed of lignified parenchyma in species of *Sparattanthelium.* **Pericycle** containing well-developed bundles of fibres in species of *Hernandia, Illigera, Sparattanthelium*; similar bundles of fibres, united by stone cells with U-shaped thickenings to form a continuous composite ring, recorded in *Gyrocarpus.* **Xylem** in the form of a more or less continuous cylinder; vessels mostly with simple perforations, but occasional scalariform plates also recorded (see 'Wood'). **Secretory cells, cystoliths,** and acicular **crystals,** similar to those described above under 'Leaf', frequently present in the axis as well.

WOOD

Vessels large (mean tangential diameter over 200 μ), sometimes only medium-sized (100–200 μ) in *Hernandia*; mostly solitary, but with some small multiples and occasionally in irregular or radial groups of 3–6. Perforations typically simple, but Solereder notes a few scalariform plates with few bars in *Hernandia*. Intervascular pitting alternate, large; pits to parenchyma often large, distinctly bordered to simple, occasionally unilaterally compound (747). According to Bailey (78) the sieve-like structures referred to by Janssonius (1154) are not true vestured pits. Mean member length 0·3–0·7 mm. **Parenchyma** moderately abundant, paratracheal, aliform (often with long wings) to confluent and, according to Garratt (747), diffuse in some specimens; terminal bands sometimes present. Strands usually of 2–4 cells; fusiform cells observed in 1 specimen of *Hernandia guianensis* Aubl. and with groups of cells composed almost entirely of fusiform cells in *Sparattanthelium guianense* Sandw. Oil cells reported (Garratt 747) to be common in *Hernandia*; with idioblasts resembling oil cells in the parenchyma of *Sparattanthelium guianense*, but filled with crystals that effervesce with hydrochloric acid. **Rays** up to 3–5 cells wide; less than 1 mm. high; uniseriates very few in *Gyrocarpus*, moderately numerous and composed of procumbent cells in *Hernandia*; 3–5 rays per mm.; homogeneous (Kribs's Types I and II). **Fibres** with numerous, small, simple pits on the radial walls. According to Record and Hess (1886) 'sometimes septate in part'. Walls thin to very thin. Mean length 1·0–1·4 mm.

TAXONOMIC NOTES

In his study of the wood anatomy of the Myristicaceae, Garratt (747) states that 'the woods of the Hernandiaceae and Myristicaceae have little in common'. Some of the points of difference that he emphasizes, such as the density of the wood and type of perforation, are of somewhat doubtful taxonomic significance and it might be more convincingly argued that the presence of oil cells, the occasional occurrence of septate fibres (recently reported by Record and Hess, 1886), and the paratracheal nature of the parenchyma indicate affinity between the families. The same characters also indicate affinity with the Lauraceae, and Garratt has already drawn attention to the points of similarity between these 2 families.

In his study of the Monimiaceae Garratt (747A) states that 'some anatomical similarity is found between the Hernandiaceae and the genera *Bracteanthus*, *Peumus* and *Siparuna*, especially the first two. The woods of the other monimiaceous genera have little in common with the Hernandiaceae; in fact they are so unlike those of this family as to imply little or no relationship.'

ECONOMIC USES

The soft, light-coloured woods of this family are not of commercial importance. Some species of *Hernandia* and *Gyrocarpus*, however, appear to be used for canoes and, according to Gamble (737), the wood of *G. jacquinii* Gaertn. is preferred above all others for catamarans. Reyes (1929) states that the wood of *Hernandia ovigera* Linn. is used in the Philippines for clogs, drawing-boards, and musical instruments.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Gyrocarpus, Hernandia, Illigera, Sparattanthelium.

(ii) FOR WOOD STRUCTURE

Gyrocarpus, Hernandia.

LITERATURE

(i) *On General Anatomy*

Kienholz **1236.**

(ii) *On Wood Structure*

Bailey **78,** Desch **574,** Gamble **737,** Garratt **747,** **747A,** Janssonius **1154,** Kanehira **1206,** **1209,** Record **1843,** **1851,** Record and Hess **1886,** Reyes **1929.**

232. PROTEACEAE

(FIG. 279 on p. 1162; FIG. 280 on p. 1164; FIG. 281 on p. 1166)

SUMMARY

(i) GENERAL

A family consisting mostly of trees and shrubs, but including a few woody herbs. They occur chiefly in Australia and South Africa, and a few are found elsewhere in the southern hemisphere. The **leaves** exhibit a diversity of form, and various physiological specializations which appear to be correlated with the nature of the arid habitats in which the plants mostly grow. In some species they are flattened, but in others narrow or even needle-shaped. **Hairs** are mostly unicellular and often thick-walled. The existence of glandular hairs has not been definitely established. A small-celled **hypoderm** is fairly frequent. **Stomata** occur on all parts of the surface of acicular or narrow leaves, but in the dorsiventral leaves are usually confined to the lower surface. In some instances they are depressed or situated in small cavities in the leaf surface. They are usually rubiaceous, but the subsidiary cells are sometimes concealed by the depression of the stomata. The **mesophyll** in flat leaves exhibits the usual type of dorsiventral structure, but in species with centric leaves the palisade tissue is in the form of an envelope surrounding a central, pith-like tissue. Variously shaped sclerenchymatous idioblasts occur in the central tissues. **Secretory cavities** appear to have been recorded only in *Adenanthos* and *Franklandia.* Solitary and clustered **crystals** occur, although somewhat infrequently and sporadically. The vascular bundles of the **veins** show special types of scattered or centric arrangement in species with acicular leaves, and in all leaves are accompanied by a varying amount of sclerenchyma, and may be vertically transcurrent. The somewhat complex vascular structure of the **petiole** is characteristic and shows variations which appear to be of considerable taxonomic interest so far as they have been investigated.

Among the most striking features of the **axis** are the broad **medullary rays** which are frequently sclerosed where they traverse the phloem. The **cork** arises superficially in such species as have been investigated. The **pericycle** contains isolated bundles of fibres or a composite ring of sclerenchyma. Tangentially arranged and scattered strands of fibres and other types of sclerenchymatous elements occur in the secondary **phloem.**

(ii) WOOD

Vessels moderately small to large, typically in tangential pairs and groups and often forming distinct tangential lines, perforations typically simple, intervascular pitting alternate, minute to moderately large, pits to parenchyma similar, members usually of medium length. **Parenchyma** typically as narrow to wide bands curving inwards between the large rays, sometimes enclosing the vessels but more characteristically with the vessels grouped on the pith or convex side; sometimes aliform to confluent. **Rays** typically of 2 distinct sizes, the larger up to 10–30 cells wide and high; usually homogeneous except for occasional sheath cells. **Fibres** usually with small bordered pits and moderately long. Traumatic vertical **intercellular canals** occasionally present. **Vasicentric tracheids** sometimes present.

LEAF

Leaves leathery and often showing specializations correlated with the arid localities in which the plants frequently occur. Dorsiventral or isobilateral to centric, the second type being characteristic of species with narrow or needle-shaped leaves. **Hairs** mostly unicellular; usually with thick walls and narrow lumina, but sometimes forming a dense felt in *Banksia*, *Dryandra*, *Grevillea*, *Hakea*; deciduous in some species. Bicellular hairs each having a short basal and a long terminal cell recorded in *Lambertia inermis* R. Br. (Fig. 279 E) and medifixed hairs (Fig. 279 F), each with a long horizontal cell supported in the middle by a short stalk cell, in species of *Grevillea* and *Hakea*. Glandular hairs not definitely recorded, but capitate hairs in sunken cavities said by Hamilton (879) to occur in *Hakea dactyloides* Cav. **Cuticle** often thick. Cells of the **epidermis** occasionally silicified, but not mucilaginous; outer wall frequently thick; papillose in *Embothrium coccineum* Forst. According to Renner (1924), the apparently several-layered epidermis, visible in transverse sections through the leaf of *Hakea leucoptera* R. Br. and certain related species, consists of a single layer of tall epidermal cells arranged obliquely to the surface.

A small-celled **hypoderm** present in the dorsiventral leaf of numerous species of *Banksia* (sometimes on both sides) and *Dryandra* as well as in species of *Franklandia*, *Grevillea*, *Stenocarpus*. **Stomata** rubiaceous in species of *Adenanthos*, *Grevillea*, *Hakea*, *Lambertia*, *Mimetes*, *Persoonia*, *Protea*, but subsidiary cells sometimes concealed in species with sunken stomata. Stomata, in most investigated species, inserted at the same level as, or even above, the leaf surface, but others sometimes surrounded by a rampart of cuticle (Fig. 279 D), or even situated in variously shaped depressions in the epidermis. Groups of stomata occur in depressions lined with a felt of delicate hairs in species of *Banksia*, *Dryandra*, *Lambertia*, &c. Stomata usually present on all parts of the surface of centric leaves, but sometimes confined to the lower side in dorsiventral leaves; usually (apart from those in depressions) parallel to one another and to the longitudinal axis of the leaf. **Mesophyll,** in transverse sections of species with isobilateral or centric leaves (Figs. 279 A–C and 280 K), usually show an envelope of 1 or more layers of palisade cells surrounding a thin- or thick-walled, central, pith-like tissue containing little or no chlorophyll, and serving for water-storage or the accumulation of starch. Variously shaped sclerenchymatous idioblasts (Fig. 279 B) also present in the central and palisade tissue; palisade-like but with short branches at either end in species of *Adenanthos*, *Grevillea*, *Hakea*, *Isopogon*, *Petrophila*, *Roupala*, *Stenocarpus*; stellate, with narrow rays, in several species of *Isopogon*; almost or completely unbranched in species of *Adenanthos*, *Bellendena*, *Hakea*, *Isopogon*, *Leucospermum*, *Nivenia*, *Sorocephalus*, *Xylomelum*; slightly and much-branched types sometimes occur together in a single species. Central portion of the mesophyll, apart from a narrow marginal zone containing cluster crystals, wholly sclerenchymatous in the acicular leaves of *Isopogon adenanthoides* Meissn. Branches of the fibres accompanying the vascular bundles in species of *Banksia*, *Dryandra*, *Grevillea* extend into the mesophyll.

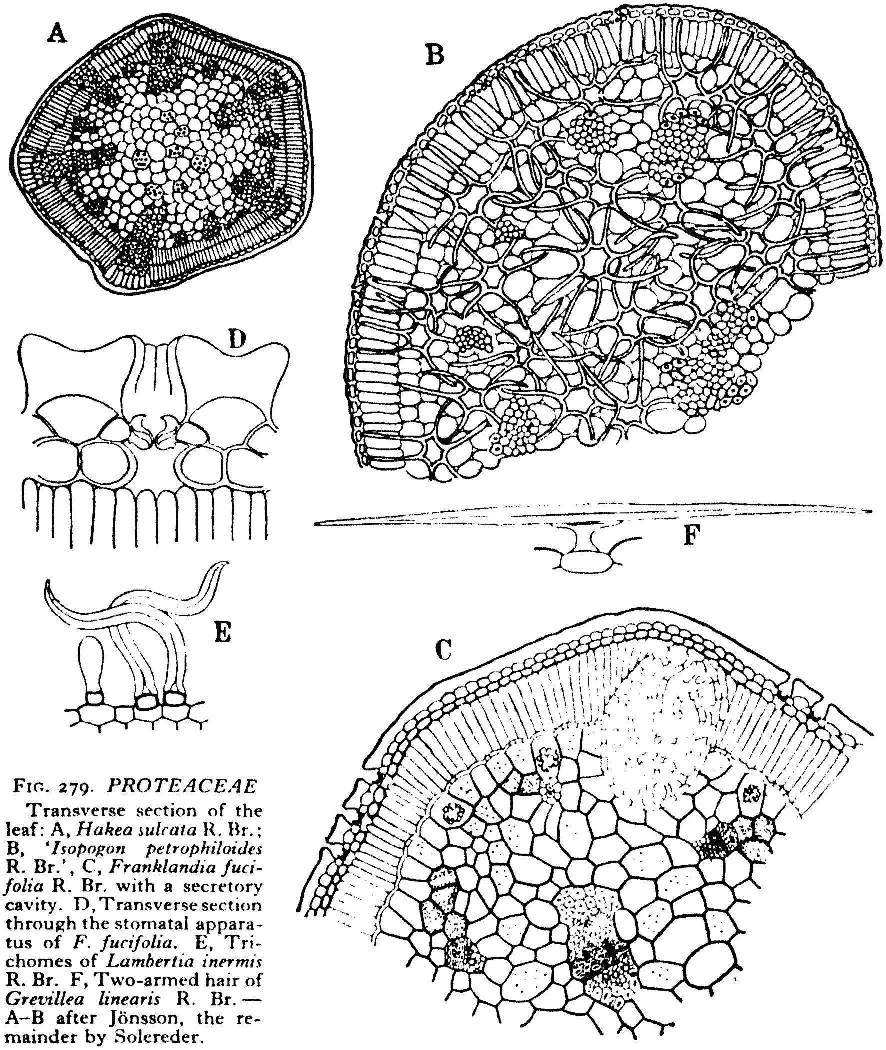


FIG. 279. *PROTEACEAE*
Transverse section of the leaf: A, *Hakea sulcata* R. Br.; B, '*Isopogon petrophiloides* R. Br.', C, *Franklandia fucifolia* R. Br. with a secretory cavity. D, Transverse section through the stomatal apparatus of *F. fucifolia*. E, Trichomes of *Lambertia inermis* R. Br. F, Two-armed hair of *Grevillea linearis* R. Br. — A–B after Jönsson, the remainder by Solereder.

Vascular bundles of the **veins** always accompanied by a varying amount of sclerenchyma; smaller veins vertically transcurrent in species of *Banksia*, *Dryandra*, *Hakea*, *Synaphea*. Vascular bundles in species with very narrow or acicular leaves either consisting of a relatively large central strand surrounded by a ring of smaller ones at the periphery of the central part of the mesophyll, or of large and small bundles scattered irregularly in the mesophyll. In other species there is a ring of bundles unaccompanied by a central strand. **Petiole** (Fig. 280 A–C, E, H, J, L), in transverse sections through the distal end, exhibiting a vascular system consisting of a crescent or cylinder of widely spaced, individually distinct, vascular bundles, but the vascular system is more complex in many of the species owing to the presence of additional strands. Vascular bundles accompanied by strongly developed strands of thick-walled fibres. Petiolar ground-tissue, in all species, including abundant secretory cells with tanniniferous contents. Shape of the petiole in transverse sections also varying considerably in different genera and species. Other features of diagnostic value in the petiole include 'cortical' in addition to 'pericyclic' sclerenchyma, especially on the adaxial side, in species of *Banksia* (Fig. 280 A), *Dryandra* (Fig. 280 B), *Grevillea* (Fig. 280 J), and *Stenocarpus* (Fig. 280 L); palisade chlorenchyma interspersed with columnar idioblasts in *Hakea*; inversely orientated, adaxial, cortical bundles in *Stenocarpus sinuatus* Endl.; sclerenchyma on both the adaxial and abaxial surfaces of each of the vascular bundles, which form a shallow crescent, in species of *Embothrium*, *Hakea* (Fig. 280 C), *Macadamia*, and *Protea* (Fig. 280 E). Fig. 280 gives some idea of the range of petiolar structure in the family. It is evident that the differences are very conspicuous and of undoubted diagnostic value. A more complete survey of the petiolar structure of this family would be necessary to determine whether the anatomical variations are of generic or specific diagnostic value. **Secretory cavities** (Fig. 279 C), lined with delicate epithelium and filled with brown contents, present in the mesophyll of species of *Adenanthos* and *Franklandia*. Secretory cavities of *Franklandia fucifolia* R. Br. specially large and visible to the naked eye as pustules on the dichotomously divided leaves. Each cavity in this species also contains a network of multicellular filaments arising from the epithelium. **Crystals** rather infrequent; solitary or clustered when present. Cubical crystals recorded by Hamilton (879) in some of the epidermal cells of *Hakea dactyloides* Cav.

Shade leaves of *Hakea dactyloides* described by Hamilton (879) as being thinner and provided with narrower cuticle and epidermis and shorter palisade cells than more exposed leaves. Stomata less numerous and situated in shallower depressions in shade leaves.

AXIS

YOUNG STEM (Fig. 280 D, F, G, I)

Cork arising in the sub-epidermis in species of *Banksia*, *Dryandra*, *Grevillea*, *Hakea*, *Persoonia*, *Stenocarpus* and probably other genera; secondary phellogens sometimes more deeply seated, e.g. in species of *Dryandra*. Component cells with thin or relatively thick sclerosed walls. Primary **cortex** frequently spongy; containing a varying proportion of stone cells in species of *Banksia*, *Dryandra*, *Embothrium*, *Grevillea*, *Hakea*, *Knightia*, *Macadamia* (Fig. 280 I), *Protea* (Fig. 280 G), and *Stenocarpus*. No cortical stone cells seen in a few species of *Embothrium*, *Hakea*, *Lomatia*, *Persoonia*, *Protea*. **Pericycle** always including well-developed bundles of fibres; the latter sometimes united by large stone cells to form a more or less continuous ring of sclerenchyma in species of *Banksia*, *Embothrium*, *Grevillea*, *Hakea*, *Knightia*, *Lomatia*, *Macadamia* (Fig. 280 I), *Persoonia*, *Roupala*, *Stenocarpus*. **Phloem**

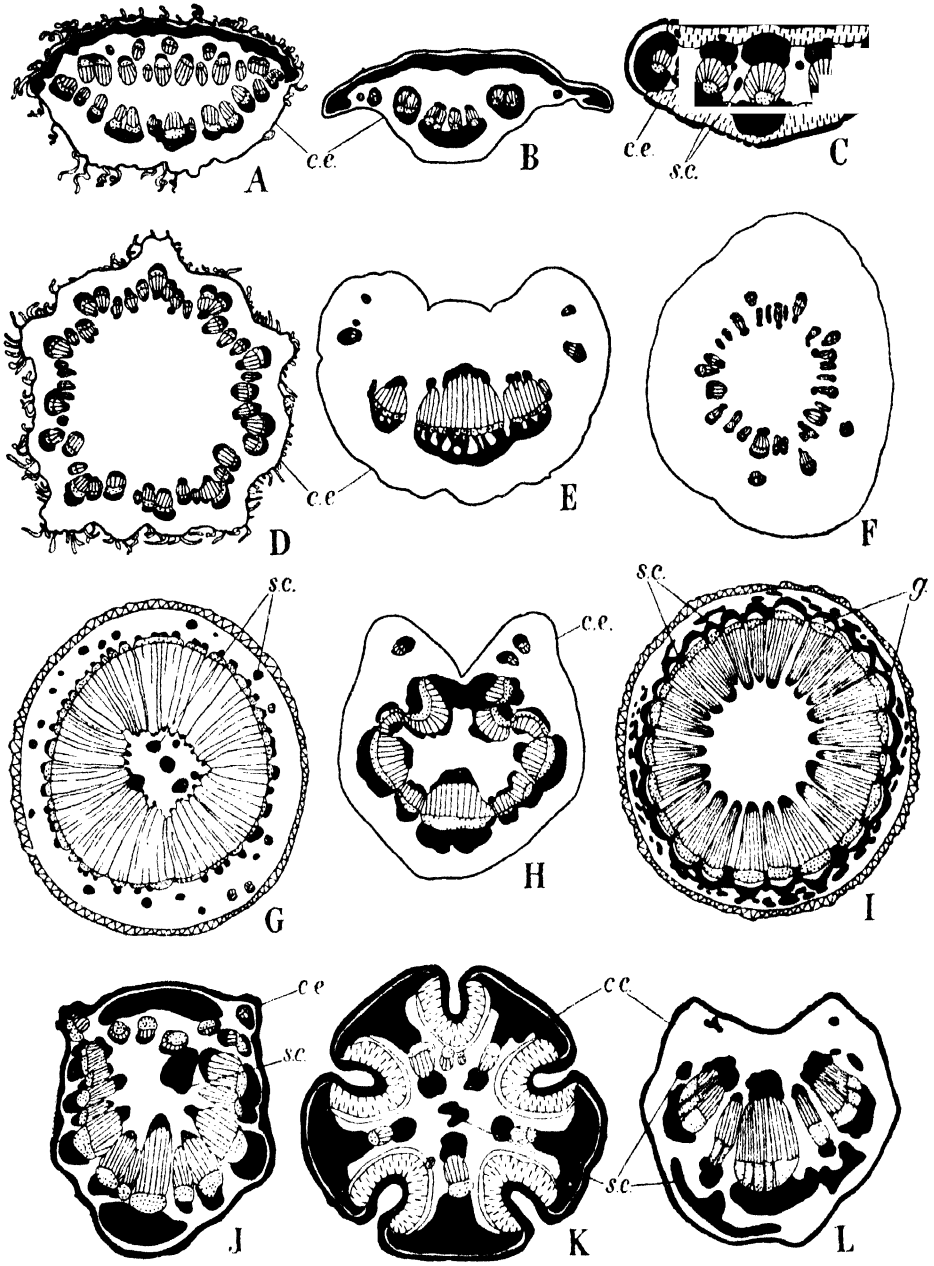


FIG. 280. *PROTEACEAE*

A, *Banksia serrata* Linn. Petiole × 18. B, *Dryandra cuneata* R. Br. Petiole × 15. C, *Hakea dactyloides* Cav. Petiole × 21. D, *Banksia littoralis* R. Br. Young stem × 15. E, *Protea cynaroides* Linn. Petiole × 8. F, *P. cynaroides* Linn. Young stem × 8. G, *P. pulchella* Andr. Stem × 5. H, *Lomatia silaifolia* R. Br. Petiole × 19. I, *Macadamia ternifolia* F. Muell. Stem × 12. J, *Grevillea densiflora* C. T. White. Petiole × 16. K, *Hakea sulcata* R. Br. var. *intermedia* Koch. Leaf × 27. L, *Stenocarpus salignus* R. Br. Petiole × 33.

c.e. Cutinized epidermis. *g.* Cells with gum-like contents. *s.c.* Stone cells, those in Fig. K containing crystals.

including strands or tangential bands of fibres, sometimes accompanied by stone cells, in species of *Banksia, Dryandra, Embothrium, Grevillea, Hakea, Lambertia, Persoonia, Stenocarpus*. No sclerenchyma noted in the phloem of *Protea*. Sieve tubes described by Solereder as provided with sieve areas throughout their length, apart from a short distance in the middle of each element. Distal ends of medullary rays, where traversing the phloem, commonly composed of large, sclerosed, pitted cells, e.g. in species of *Banksia, Dryandra, Grevillea, Hakea, Knightia, Lomatia, Macadamia* (Fig. 280 I); frequently wedge-shaped in transverse sections, this feature noted at Kew particularly in species of *Banksia, Macadamia, Protea*.

Xylem appearing in transverse sections of sufficiently young stems as a more or less sinuous circle of closely placed, but individually distinct, vascular bundles (Fig. 280 D, F). This character, noted at Kew in species of *Banksia, Dryandra*, and *Hakea*, probably occurs in the other genera as well. Xylem in more mature stems forming a cylinder traversed by broad rays (Fig. 280 G, I), the latter sometimes accompanied by a few narrow, uniseriate rays. The tangential arrangement of the vessels, described more fully under 'Wood', is visible in quite young stems. Vessels usually with simple perforations (see 'Wood'). **Pith** exhibiting rather a wide range of types and varying considerably in diameter in different genera and species; sometimes, e.g. in species of *Banksia* and *Lomatia*, conspicuously heterogeneous and consisting of empty cells mixed with others having starchy and tanniniferous contents; including numerous stone cells in *Knightia* and *Protea* (Fig. 280 G); small and composed of highly sclerosed cells in *Stenocarpus*; not strikingly heterogeneous in *Dryandra* and *Hakea*. Stone cells also noted in the pith of *Protea*. **Cortical vascular bundles** (Fig. 280 G) observed in species of *Banksia, Dryandra*, and *Protea*. **Crystals** rare; small, solitary cubes noted in the sclerosed cells at the distal ends of the rays in species of *Banksia, Dryandra, Grevillea, Hakea, Knightia, Macadamia, Stenocarpus*; hexagonal crystals noted in the corresponding position in *Hakea oleifolia* R. Br. grown in the Scilly Islands. No crystals seen in the distal ends of the rays in species of *Embothrium* and *Lambertia*. Infrequent cluster crystals observed in the pith of one species of *Protea* grown in the Scilly Islands. **Secretory elements.** Cells with unidentified but probably tanniniferous contents frequent or abundant in the cortex, phloem, medullary rays, and pith of the species examined at Kew.

WOOD (Fig. 281)

Vessels mostly small to medium-sized (mean tangential diameter 50–200 μ), occasionally large (more than 200 μ), e.g. in some species of *Cardwellia, Helicia*, and *Panopsis*; solitary and in tangential and radial multiples; characteristically associated with the parenchyma bands and with them forming festoons between the large rays (Fig. 281 A); the vessels sometimes very numerous and themselves forming tangential bands that may have relatively little parenchyma (Fig. 281 C and G), e.g. in *Guevina, Lomatia* (1886), and *Persoonia*; tending to be solitary in *Protea* and *Faurea discolor* Welw.; with little tangential pattern in some species of *Beauprea, Brabejum* (2158), *Embothrium* (Fig. 281 I), *Finschia, Hicksbeachia, Isopogon* (2158), *Musgravea, Panopsis* (1886), *Persoonia* (2158), *Protea, Stenocarpus*, and *Xylomelum*; mostly 5–15 per sq. mm., but fewer in some species of *Embothrium, Helicia, Panopsis,*

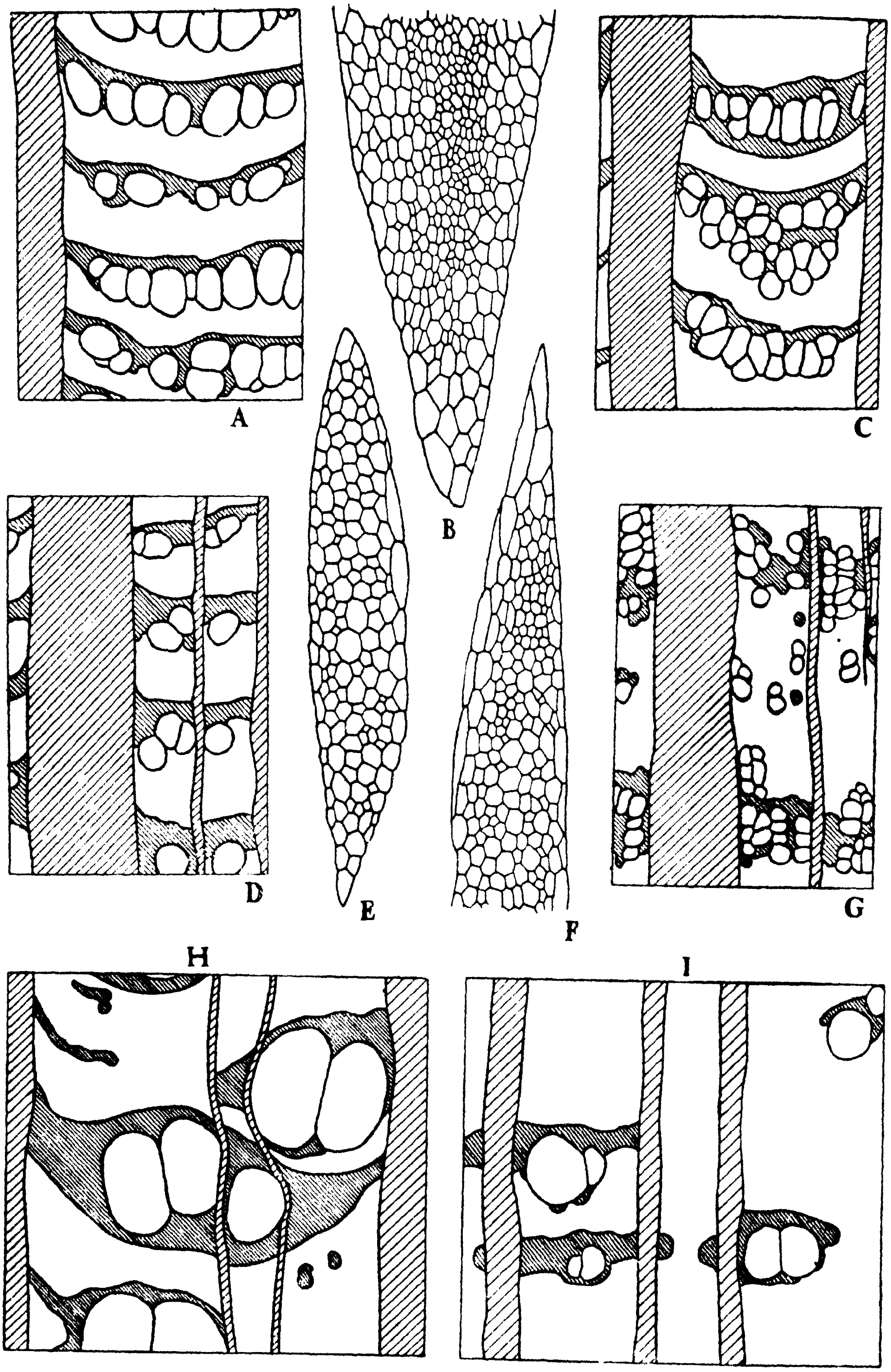


Fig. 281. *PROTEACEAE*

A, *Orites excelsa* R. Br. B, *Cardwellia sublimis* F. v. Müll. C, *Guevina avellana* Molina. D, *Faurea macnaughtonii* Phillips. E, *Leucadendron argenteum* R. Br. F, *Orites excelsa* R. Br. G, *Persoonia* sp. H, *Cardwellia sublimis* F. v. Müll. I, *Embothrium wickhami* F. v. Müll.

Protea, and *Stenocarpus*; ring-porous, according to Scala (2022), in *Embothrium*; spiral thickening observed or reported (1206, 1886, 2158) in *Dryandra formosa* R. Br., *Grevillea baueri* R. Br., *Guevina avellana* Mol., *Helicia formosana* Hemsl., *H. cochinchinensis* Lour., and *Persoonia acerosa* Sieb. Perforations typically simple, but some rare scalariform plates with few bars occur in *Guevina* and, according to Record and Hess (1886), in the small vessels of some other species. Intervascular pitting alternate, small in *Cardwellia*, *Faurea*, *Finschia*, *Hicksbeachia*, *Knightia*, *Leucadendron*, and *Xylomelum*, and minute in *Macadamia*, *Roupala*, and *Stenocarpus*; moderately large in the other genera examined. Pits to ray and wood parenchyma cells similar to the intervascular pitting, occasionally unilaterally compound in *Grevillea robusta* Cunn. Often with dark, reddish contents. Mean member length usually 0·3–0·5 mm., but up to 0·9 mm., according to Kribs, in *Panopsis cayennensis* Kl. **Parenchyma** paratracheal; most commonly as narrow bands between the large rays, 1–2 cells wide and curving inwards towards the pith, and with the vessels, as it were, strung along the inner or pith sides of the bands (Fig. 281 A); the bands sometimes broader and tending to enclose the vessels, e.g. in *Beauprea*, *Cardwellia* (Fig. 281 H), *Roupala*, *Stenocarpus*, and *Xylomelum*; occasionally with most of the bands independent of the vessels (apotracheal), e.g. in some species of *Helicia*, *Musgravea*, and *Stenocarpus*; sometimes aliform to confluent and not distinctly banded, e.g. in *Embothrium wickhami* F. v. Müll. (Fig. 281 I) and *Protea* spp.; occasionally with some isolated cells scattered among the fibres, e.g. in *Cardwellia*, *Faurea*, and *Hicksbeachia*. Strands usually of 2–4 cells, sometimes up to 8 cells, e.g. in *Helicia* and *Panopsis*, sometimes rarely of more than 2 cells, e.g. in *Protea*. Sometimes locally storied in *Stenocarpus*. **Rays** of 2 distinct sizes, except in *Beauprea*, *Leucadendron*, *Macadamia*, and *Persoonia*, in which sizes transitional between the largest and smallest are commonly present; the larger rays commonly up to 15–30 cells wide in most species, not more than 9–12 cells wide in some species of *Embothrium*, *Leucadendron*, and *Persoonia*, and sometimes more than 30 cells wide in some species of *Cardwellia*, *Faurea*, and *Helicia*; the widest rays usually between 0·2 and 0·3 mm. wide, but not uncommonly much wider, e.g. 0·5–0·75 mm. in some species of *Cardwellia*, *Faurea*, *Guevina*, *Helicia*, *Knightia* (744), *Panopsis*, *Stenocarpus*, and *Xylomelum*, and sometimes up to about 1·3–1·5 mm., e.g. in *Banksia aemula* R. Br. and *Helicia* spp. (1154); typically more than 1 mm. and often several mm. high; uniseriates moderately numerous in *Persoonia* and *Protea*, but typically rather few and sometimes very few, e.g. in some species of *Embothrium*, *Finschia*, *Helicia*, *Orites*, and *Panopsis*, commonly 1 or 2 cells high and varying between upright cells only and nearly all procumbent; mostly 1–4, and up to 6, rays per mm.; the large rays usually homogeneous except for occasional sheath cells, sheath cells being most prominent in some species of *Beauprea*, *Embothrium*, *Finschia*, *Grevillea*, *Hicksbeachia*, *Orites* (Fig. 281 F), *Panopsis*, *Protea*, and *Stenocarpus*; sometimes with markedly smaller cells in the middle of the ray, e.g. in *Cardwellia sublimis* F. v. Müll. (Fig. 281 B). Numerous stone cells present in *Stenocarpus salignis* R. Br. Oil cells reported by Williams (2430) in *Embothrium* and *Roupala*, but not observed in the species examined by the author. **Fibres** typically with bordered pits, the apertures exserted; the borders sometimes distinct, e.g. in some species of *Faurea*, *Persoonia*, *Protea*, *Stenocarpus*, and *Xylomelum*, usually small and rather indistinct, and sometimes very small and indistinct or lacking, e.g. in some species of *Finschia*, *Grevillea*, *Helicia*, *Hicksbeachia*, *Knightia*, and *Leucadendron*; pits usually more abundant on the radial walls but sometimes equally abundant on both radial and tangential walls. Walls usually rather thick and sometimes very thick, e.g. in *Banksia*, *Finschia*, *Macadamia*, and *Roupala*. Reported (744) to have spiral thickening in the tips of the fibres in *Knightia*. Mean length 1·2–2·7 (mostly 1·6–1·7) mm. **Intercellular canals** of the traumatic vertical type reported (1851) to be present occasionally in *Banksia*, *Cardwellia*, and *Grevillea*. **Vasicentric tracheids** reported (360, 1206, 2400) in some species of *Darlingia*, *Faurea*, *Grevillea*, *Helicia*, *Musgravea*, and *Stenocarpus*.

TAXONOMIC NOTES

FROM WOOD STRUCTURE

The woods of this family form a natural group with distinctive structure. Within the family the wood anatomy suggests that the constitution of some of the genera might be reconsidered with advantage. *Embothrium*, for example, appears to include 2 markedly different types of wood structure, such as can be seen in *E. wickhami* F. v. Müll. on the one hand and *E. coccineum* Forst. and *E. weberbaueri* Perk. on the other. Janssonius (1154) notes that the Javanese species of *Helicia* fall into 2 groups that differ more than is usual among species of the same genus.

Williams (2430) considers that the woods of this family suggest the Dilleniaceae; apart from the large rays in both, there seems to be little to support this view and much to throw doubt on it.

ECONOMIC USES

Many of the Proteaceae are cultivated for ornamental purposes where the climate is sufficiently warm. The fruits of a few species are edible.

The very large rays that are characteristic of this family give the woods a striking, oak-like figure on radial surfaces and many of them find a use as decorative or fancy timbers. Many of the Australian species are known as Silky Oaks, but most of the timber exported under this name appears to be derived from *Cardwellia sublimis* F. v. Müll. The timbers are used for joinery and cabinet-work, panelling, veneers, and plywood. *Grevillea robusta* A. Cunn. has been widely planted in the tropics for fuel and as a shade tree for coffee.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Adenanthos, Aulax, Banksia,* Bellendena, Dryandra,* Embothrium,* Franklandia, Grevillea,* Hakea,* Isopogon, Knightia,* Lambertia,* Leucospermum, Lomatia,* Macadamia,* Mimetes, Nivenia, Persoonia,* Petrophila, Protea,* Roupala, Sorocephalus, Stenocarpus,* Synaphea, Xylomelum.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Banksia, Beauprea, (Brabejum), Cardwellia, (Darlingia), (Dryandra), Embothrium, Faurea, Finschia, (Franklandia), Grevillea, Guevina, Helicia, Hicksbeachia, (Isopogon), Knightia, Leucadendron, Lomatia, Macadamia, Musgravea, Orites, Panopsis, Persoonia, Protea, Roupala, Stenocarpus, Symphyonema, Xylomelum.

LITERATURE

(i) *On General Anatomy*

Audas and Morris **56**, Francis **706**, Hamilton **879**, Renner **1924**, Shelton **2086**.

(ii) *On Wood Structure*

Baker **105**, Baker and Smith **113**, Beekman **167**, Benoist **170**, den Berger **179**, Chalk *et al.* **360**, Cozzo **494**, Dadswell **525**, Dadswell and Record **533**, Garratt **744**, Janssonius **1154**, Jolly **1188**, Kanehira **1206**, **1209**, Kribs **1283**, Record **1800**, **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**, Scala **2022**, **2025**, Scott **2075**, Tupper **2295**, Welch **2400**, Williams **2430**.

233. THYMELAEACEAE

(FIG. 30 on p. 118; FIG. 282 on p. 1172; FIG. 284 on p. 1182; FIG. 285 on p. 1186)

SUMMARY

(i) GENERAL

A family consisting mostly of shrubs and trees, but including a few herbs. It occurs chiefly in South Africa, Australia, and other warm temperate regions, but is less common in the tropics. Some species of *Passerina* have ericoid leaves with woolly grooves on the upper surface, which have been shown by Thoday (2249) to become almost or completely closed during dry weather. The leaf in other genera is usually dorsiventral or occasionally isobilateral. In adpressed leaves the mesophyll is sometimes inverted, the palisade tissue being towards the more exposed lower surface. **Hairs** are nearly always unicellular, but sometimes 2-armed. The **epidermis** of the leaf frequently includes mucilaginous cells. **Stomata** occur on both surfaces or are confined to the lower side, except in species of *Passerina* with adpressed leaves, where they are to be found only on the adaxial side. They are generally ranunculaceous, except in some genera where papillose elongations of the walls of a rosette of epidermal cells surrounding the stomata make the latter appear as if sunken in pits. The **mesophyll** frequently includes sclerenchymatous elements. The most characteristic and widespread feature of the young axis is the presence of **intraxylary phloem** in all genera except the moss-like *Drapetes*. Extensions of this tissue into the petiole and midrib have been recorded only in certain genera. **Interxylary phloem** also occurs in some of the genera. **Cork** arises superficially. The triangular **phloem** strands, with the apices towards the exterior, contain variously arranged fibres which appear as silken threads in transversely fractured material. **Crystals** are secreted in a variety of forms, but do not appear to be of much taxonomic value since they are somewhat variable even within a single species.

(ii) WOOD

Vessels small, sometimes in dendritic radial or oblique groups, such genera often with spiral thickening and tending to be ring-porous; perforations simple, intervascular pitting alternate, vestured and small, pits to parenchyma similar, members of medium length to extremely short. **Parenchyma** paratracheal, varying from scanty to aliform and confluent, and sometimes intermediate between aliform and apotracheal bands, terminal bands often present, tending to be storied. **Rays** usually either predominantly uniseriate or up to 2–4 cells wide with few uniseriates, usually either homogeneous or composed entirely of square to upright cells. **Fibres** with bordered pits, moderately to extremely short. **Tracheids** sometimes present, usually with spiral thickening. **Included phloem** of the foraminate type present in several genera. Large radial canals or channels sometimes present.

LEAF

Usually dorsiventral, but isobilateral to centric structure recorded in species of *Diarthron*, *Pimelea* (Betts 188), *Thymelaea*. **Hairs** said to be exclusively unicellular, but sometimes tending to be 2-armed, especially in *Daphnopsis*. **Cuticle** usually smooth. **Epidermis** generally composed of low cells, but taller ones recorded in a few species of *Dais*, *Daphnopsis*, *Drapetes*, *Thymelaea*; anticlinal walls of cells on the upper surface generally straight, and of those on the lower side straight or sinuous. Epidermal cells sometimes arched outwards in *Linostoma*; papillose on the lower surface in species of *Daphne*; mucilaginous in species of *Arthrosolen* (Fig. 284 A), *Chymococca*, *Cryptadenia*, *Daphne*, *Diarthron*, *Dicranolepis*, *Edgeworthia*, *Gnidia*, *Lachnaea*, *Lagetta*, *Lasiadenia*, *Lasiosiphon*, *Leucosmia*, *Linodendron*, *Lophostoma*, *Ovidia*, *Passerina*, *Peddiea*, *Phaleria*, *Pimelia*, *Struthiola*, *Synaptolepis*, *Thymelaea*, *Wikstroemia*. Scattered cells with strongly thickened walls sometimes occur in the epidermis of species of *Phaleria*. A **hypoderm** of mucilaginous cells recorded in *Daphne* by Hill (971), and on both sides of the mesophyll in *Pimelea suteri* T. Kirk by Betts (188).

Stomata present on both surfaces or confined to the lower side; occurring in the grooves on the upper surface of species of *Passerina* with adpressed leaves; usually ranunculaceous. Single stomata, situated at the base of flask-shaped receptacles (Fig. 284 B, E) formed by papillose elevations of the surrounding epidermal cells, recorded in species of *Daphne* (Hill 971), *Edgeworthia*, *Enkleia*, *Linodendron*, *Linostoma*, *Passerina*, *Synaptolepis*. **Mesophyll** composed wholly of isodiametric cells in species of *Drapetes*. Palisade cells generally short. Mesophyll showing an inverted structure, with palisade tissue on the abaxial (external) and spongy tissue on the adaxial side, in species of *Passerina* with adpressed leaves. Mesophyll including irregular sclerenchymatous fibres in species of *Daphne*, *Daphnopsis*, *Enkleia*, *Gyrinops*, *Lasiophyton*, *Peddiea*, *Stephanodaphne*. Leaf margins supported by bundles of sclerenchymatous elements in species of *Daphnopsis*, *Dicranolepis*, *Passerina* (Thoday 2249), *Synaptolepis*. According to Thoday (2249) the fibres in *Passerina* extend laterally beneath the epidermis. In surface view these hypodermal fibres can be seen taking an irregular course, growing apically and occasionally becoming branched. Vascular bundles of the **veins** usually accompanied by sclerenchyma, but surrounded by a sheath of parenchymatous cells containing tannin in *Pimelea suteri* according to Betts (188). **Intraxylary phloem** recorded by Léandri (1325) and cited by Domke (595) in the petiole and midrib in species of *Aquilaria*, *Daphnopsis*, *Edgeworthia*, *Englerodaphne*, *Enkleia*, *Eriosolena*, *Funifera*, *Goodallia*, *Gyrinops*, *Gyrinopsis*, *Hyptiodaphne*, *Lagetta*, *Lasiadenia*, *Leucosmia*, *Linodendron*, *Lophostoma*, *Phaleria* (except *P. coccinia* F. Muell.), *Rhamnoneuron*, *Stephanodaphne*, *Synaptolepis*, *Wikstroemia*. Intraxylary phloem not recorded in the corresponding positions in certain species of *Chymococca*, *Cryptadenia*, *Dais*, *Daphne*, *Diarthron*, *Dicranolepis*, *Dirca* (but described and figured in the midrib of *D. palustris* Linn. by Choquette (407)), *Drapetes*, *Gnidia*, *Lachnaea*, *Lasiosiphon*, *Linostoma*, *Octolepis*, *Ovidia*, *Passerina*, *Peddiea*, *Pentathymelaea*, *Phaleria coccinia*, *Pimelea*, *Schoenobiblus*, *Stellera*, *Struthiola*, *Thymelaea*.

Petiole, in transverse sections through the distal end, exhibiting various types of arc-shaped vascular strands in the few species examined at Kew (Fig. 285 A, B, C, E). In *Daphne* provided with a shallow, crescentic, median vascular strand, accompanied in some species by accessory bundles in the wings. A rather thick, crescentic, median vascular strand, with short but strongly incurved ends, noted in *Dais* (Fig. 285 A), and an almost cylindrical strand with well-developed intraxylary phloem in *Lagetta* (Fig. 285 D). For further details concerning the vascular structure of the petiole see Léandri's (1325) paper. The petiolar vascular structure, in at least certain members of the family, shows a very considerable range of structure in sections taken at different levels in a single petiole. **Crystals** secreted in the form of solitary rhombohedra, very elongated prisms (Fig. 284 D), clusters, or sand; styloids present according to Holm (1006) in *Dirca palustris*. The distribution of these different kinds of crystals is of little taxonomic significance, because all of these and intermediate types occur within a single species.

AXIS

YOUNG STEM (Fig. 285 D, F)

Cork arising in the epidermis or outermost part of the cortex; component cells mostly with uniformly thickened walls; sometimes rather broad, especially in species from dry habitats. Outer part of the primary **cortex** collenchymatous in at least certain species of *Dais*, *Daphne*, *Dirca*, *Gnidia*, *Lagetta*, *Pimelea*; inner part frequently mucilaginous and becoming disorganized; containing palisade tissue in species of *Gnidia* and *Thymelaea*. **Pericycle,** of all of the species examined at Kew, including strands of fibres at the outer periphery of the phloem, and not very readily distinguished from those in the phloem itself; a continuous ring of pericyclic fibres not observed. **Phloem** (Fig. 285 D, F) commonly rather wide, especially in *Daphne*; usually appearing in transverse sections as triangular groups with outwardly directed apices and separated from each other by the enlarged distal ends of the otherwise narrow medullary rays. Distal ends of the rays not enlarged in certain species, e.g. according to Betts (188) in *Pimelea suteri* T. Kirk. Fibres very common in the phloem, where, in transverse sections, they appear to be scattered, in the form of dendritic figures, in tangential bands, or concentrically arranged in different genera and species. Fibres provided with lignified or unlignified walls of varying thickness; frequently devoid of pits; never septate; exhibiting various forms of indentation of the walls; ends of the elements often clavate but seldom pointed. Phloem fibres sometimes visible to the naked eye as silky threads extending outwards from the broken ends of young branches. Vogl (2338) found the number and arrangement of the phloem fibres to be of specific diagnostic value in *Daphne*, but this should not be accepted without a fresh investigation on a wide range of material.

Xylem in the form of a continuous cylinder traversed by narrow rays in the species of *Dais*, *Daphne*, *Dirca*, *Gnidia*, *Lagetta*, *Pimelea* available for

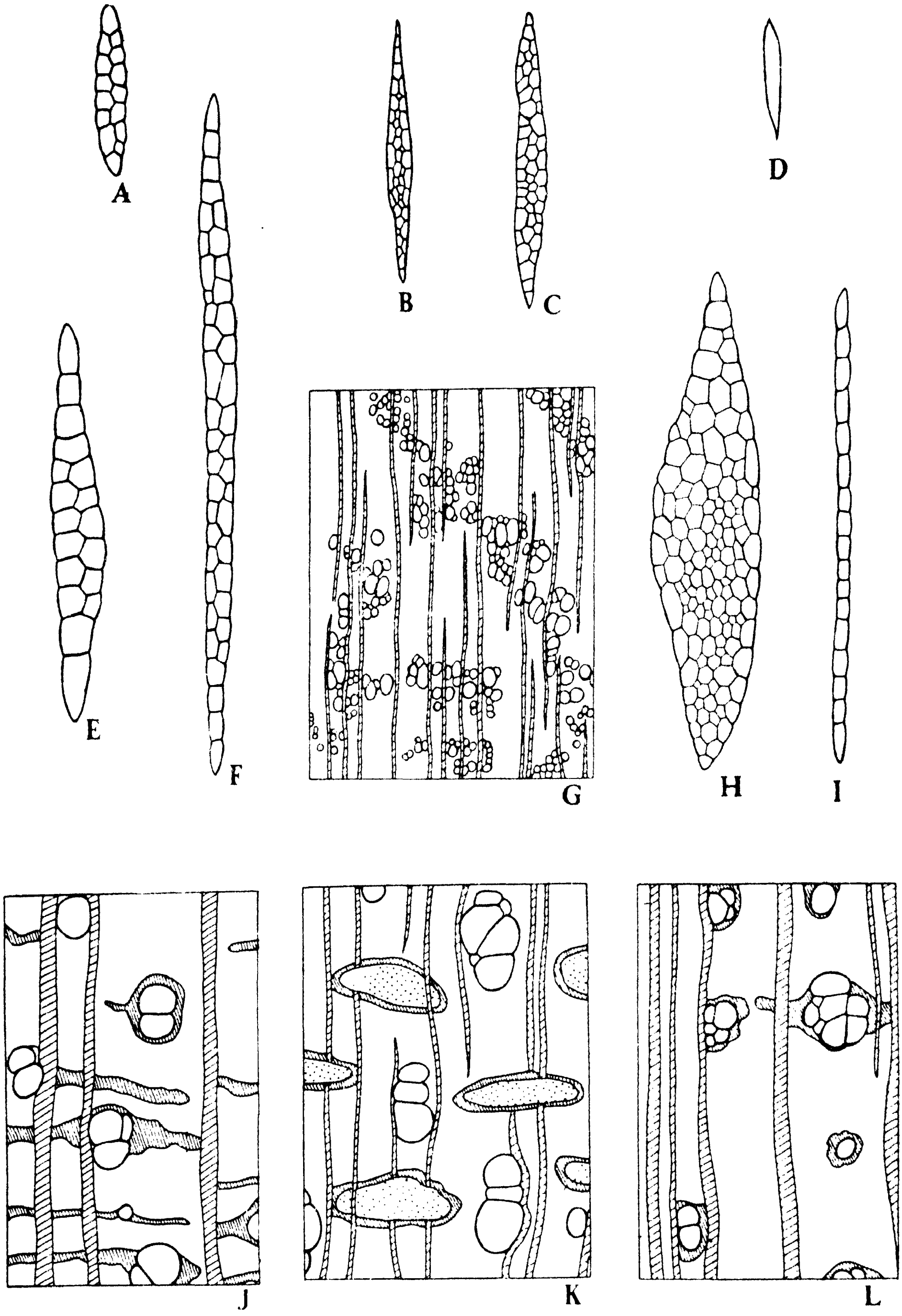


Fig. 282. *THYMELAEACEAE*

A, *Daphnopsis loranthifolia* Standley. B, *Wikstroemia elliptica* Merrill. C, *Phaleria disperma* Baill. D, *Dirca palustris* Linn. Cambiform fibre × 90. E, *Daphnopsis phillipiana* Krug. F, *Schoenobiblus peruviana* Standley. G, *Passerina hirsuta* Linn. H, *Lasiosiphon glaucus* Fresen. I, *Aquilaria agallocha* Roxb. J, *Lagetta lintearia* Lam. K, *Aquilaria malaccensis* Lam. L, *Phaleria disperma* Baill.

examination. Vessel perforations simple. Vessel distribution, in young stems up to 1 cm. in diameter, described by Léandri (1325), whose work has been discussed by Domke (595), as follows:

(i) Vessels isolated or in groups of 2 or 3 in *Chymococca*, *Craterosiphon*, *Cryptadenia*, *Dais*, *Diarthron*, *Dicranolepis*, *Englerodaphne*, *Enkleia*, *Gnidia*, *Gyrinops*, *Lachnaea*, *Lagetta*, *Linostoma*, *Lophostoma*, *Passerina*, *Stellera*, *Stephanodaphne*, *Struthiola*, *Synaptolepis*.

(ii) Vessels tending to be in radial rows in *Aquilaria*, *Daphne*, *Daphnopsis*, *Edgeworthia*, *Funifera*, *Goodallia*, *Gyrinopsis*, *Hyptiodaphne*, *Lasiadenia*, *Linodendron*, *Peddiea*, *Phaleria*, *Pimelea*, *Rhamnoneuron*, *Wikstroemia*.

(iii) Vessels tending to be in tangential rows in *Dirca*, *Pentathymelaea*, *Thymelaea*.

(iv) Vessels in radial and tangential rows in *Eriosolena* and *Ovidia*.

Judging from the limited material examined at Kew the above classification based on vessel distribution is not very reliable since the 4 types are by no means sharply defined. It should, therefore, be accepted with reserve.

Pith composed of lignified and unlignified cells; stone cells recorded by Solereder in species of *Drapetes*, *Lasiosiphon*, *Linostoma*, *Lophostoma*, *Pimelea*, *Stellera*, *Synaptolepis*. Central part of the pith sometimes spongy and tending to become disorganized.

Intraxylary phloem (Fig. 285 D, F) always present except in the ericoid *Kelleria*, the moss-like *Drapetes*, and the anomalous *Microsemma* and *Solmsia*. The last 2 genera are described separately on pp. 1175–6. Intraxylary phloem frequently accompanied, along its inner margin, by scattered fibres, similar to those in the extraxylary phloem; sometimes extending into the petiole and midrib (see on p. 1170). **Secretory cells** observed at Kew only in the outer cortex of *Lagetta* and in the cortex and pith of *Pimelea*, but recorded in *Octolepis* and *Solmsia* by Domke (595). Tanniniferous elements present in *Pimelea suteri* T. Kirk according to Betts (188). Clustered and solitary **crystals** noted in species of *Dais*, *Dirca*, *Lagetta*, *Pimelea* (pro parte); none seen in *Daphne* (several species), *Gnidia* (1 species), *Pimelea* (1 species).

Wood (Fig. 282)

Vessels typically small (less than 100 μ mean tangential diameter), sometimes slightly larger, e.g. in *Lagetta* and *Lasiosiphon*, and sometimes extremely small (less than 25 μ), e.g. in *Daphne*, *Ovidia*, and *Passerina*; often with a tendency to a loose tangential arrangement; irregular clusters sometimes common (Fig. 282 L); in distinctive radial or oblique groups (dendritic) in *Daphne*, *Dirca*, *Ovidia*, and *Passerina* (Fig. 282 G); 4–15 per sq. mm. in the woods without a dendritic pattern; semi-ring-porous in *Dirca* and *Passerina*; spiral thickening observed or recorded (1851, 2158) in some species of *Dais*, *Daphne*, *Daphnopsis*, *Dirca*, *Lachnaea*, *Ovidia*, *Passerina*, *Phaleria*, *Pimelea*, *Stellera*, and *Wikstroemia*. Perforations simple. Intervascular pitting alternate, usually small to very small, but occasionally medium-sized; vestured (78); pits to ray and wood parenchyma similar. Solid deposits sometimes present, e.g. in *Aquillaria* and *Daphne*; the abundant deposits that saturate the 'Eaglewood' or 'Aloewood' obtained from *Aquilaria* are not present in the normal wood. Mean member length 0·15–0·4 mm. **Parenchyma** paratracheal; very sparse and limited to rare cells associated with the vessels in *Dirca*, *Gyrinops*, and *Passerina*; moderately abundant and intermediate between aliform and apotracheal bands in some species of *Daphne* and *Lagetta* (Fig. 282 J), and, according to Solereder, in *Dirca* and *Pimelea*; with short bands touching the abaxial sides of the vessels in *Wikstroemia*; occasionally with a few cells scattered among the fibres; narrow terminal bands sometimes present, e.g. in some species of *Daphne*, *Daphnopsis*, and *Schoenobiblus*. Strands usually of 4 cells, but mostly of 2 cells in some species of *Daphnopsis*, *Lasiosiphon*, *Phaleria*, and *Wikstroemia*; Janssonius (1154) notes some fusiform cells, which are shorter than the strands, in *Phaleria* and *Wikstroemia*. Sometimes tending to be storied, and distinctly storied in *Daphnopsis loranthifolia* Standl. and *Lasiosiphon glaucus* Frisan. **Rays** usually 2–4 cells wide, up to 9 cells in *Lasiosiphon glaucus*; and predominantly uniseriate in *Aquilaria*, *Daphne*, *Gyrinops*, and *Passerina*; about 1 mm. high or lower; uniseriates usually few in woods with multiseriate rays and composed of cells similar to those of the multiseriate rays; up to 16 rays per mm. in genera with exclusively uniseriate rays, mostly 5–10 per mm. in the others; rays homogeneous (Kribs's Types I and III), or almost so, in *Ovidia*, *Passerina*, *Phaleria*, and *Wikstroemia*; cells tending to be all square or upright in the other genera, except in *Daphnopsis loranthifolia* and *Lasiosiphon*, in which the rays are heterogeneous, with 1–3 marginal rows of square or upright cells. Storied in *Daphnopsis loranthifolia* and some species of *Lasiosiphon* (1851) and *Schoenobiblus* (1886). **Fibres** typically with numerous bordered pits, mostly on the radial walls and sometimes in more than 1 row, the borders small to distinct; Solereder notes simple pits in species of *Diarthron*, *Edgeworthia*, and *Lasiadenia*. Walls typically thin, but occasionally thick, e.g. in *Peddiea volkensii* Gilg. Mean length 0·3–0·9 mm. Extremely short and cambiform in *Daphne*, *Dirca* (Fig. 282 D), and, according to Record and Hess (1886), in *Lasiadenia*. **Tracheids.** The vessels of *Daphne*, *Dirca*, and *Ovidia* are mixed with very narrow, short cells with spiral thickening, which appear to be vasicentric tracheids, mixed with a few vascular tracheids and some extremely small vessels; Kanehira refers (1206) to the presence of tracheids, without spiral thickening, in *Wikstroemia indica* C. A. Mey. **Included (interxylary) phloem** of the 'foraminate' type recorded by Pfeiffer (1712) and by Léandri (1325) in *Aquilaria*, *Aquilariella*, *Enkleia*, *Gyrinops*, *Gyrinopsis*, *Lachnolepis*, *Linostoma*, *Lophostoma*, and *Synaptolepis*; with round to oval strands of included phloem surrounded by narrow sheaths of parenchyma (Fig. 282 K), which, in the material examined of *Aquilaria* and *Gyrinops*, consists entirely of fusiform cells; often with several strands linked together tangentially, e.g. in *Gyrinops*; long bast fibres often conspicuous in the phloem bundles of *Aquilaria* and *Gyrinops* and possibly in other genera not available to the author. In *Dirca palustris* L. narrow bands of anomalous tissue occur at irregular, and often wide, intervals (see also under 'Anomalous Structure' below). Large **radial channels** or **canals** are reported by Record (1851) to be sometimes present in *Daphne*, *Daphnopsis*, *Lasiosiphon*, and *Schoenobiblus*.

ANOMALOUS STRUCTURE

The genera in which interxylary phloem is known to occur have been listed under 'Wood'. In addition Joshi (1197) has described anomalous thickening in the stem and root of *Wikstroemia chamaejasme* (L.) Domke (syn. *Stellera* *chamaejasme* Linn.). In old stems of this species there are concentric zones of xylem and phloem, separated from one another by parenchyma. Interxylary phloem is sometimes formed in the outer rings as well. Anomalous thickening in the root of the same species starts from a secondary cambium formed from the living cells of the rays and xylem on the inside of the primary cambium. The tissues produced by the secondary cambium are inversely orientated. The secondary cambium may remain free from, but sometimes becomes continuous with, the primary cambium at a number of points. Later separate vascular cylinders are formed in the peripheral part of the root. Small vascular cylinders are also formed in the centre of the root through the irregular development of the secondary cambium. Joshi also observed interxylary phloem in the root.

Lashevski (1321) has shown how, in the rhizome of '*Daphne julia* K. Pol.', the xylem is dissected into 4 fan-shaped groups, owing to the abnormal production of parenchyma. In Lashevski's opinion the structure of the rhizome indicates that '*D. julia*' may have been evolved from ancestors with the liane habit. According to Léandri (1324) there are numerous pseudosteles in old rhizomes of *D. gnidium* Linn. This anomaly is initiated by the development of secondary cambia in the xylem, and by the formation of normal cambium. Here again the structure recalls that of lianes. More recently Léandri (1326) has described the development of concentric cambia, outside the normal cambium, in several African species of *Gnidia*. This anomaly has been seen only in the tuberous upper end of the subterranean axis at the bases of plants in which, after being destroyed by fire, the principal branches have been replaced by short lateral growths arising from adventitious buds.

ECOLOGICAL ANATOMY

Léandri (1325) has investigated the structure of numerous members of the family in relation to habitat, and found that, whilst characters like sunken stomata, thick cuticle, and the centric structure of the mesophyll occur in species from dry localities, the anatomical pattern does not show any profound modification in relation to habitat.

MICROSEMMA

Microsemma salicifolia Labill. is a small tree or shrub with leathery leaves. It is described separately here because the microscopical structure, like that of the exomorphic features, differs in certain respects from the other genera in the Thymelaeaceae. The absence of intraxylary phloem is especially noteworthy. The following particulars are based partly on observations made on material from the Kew herbarium and partly on Beauvisage's (163) description.

LEAF

Dorsiventral. **Hairs** infrequent, fairly long, unicellular, with thickened (often spirally) walls. Cells of the upper **epidermis** provided with straight anticlinal walls. **Stomata** very numerous, confined to the lower surface, each surrounded by 5 or 6 subsidiary cells differing from those of the remainder of the epidermis in being filled with granular contents. **Mesophyll** consisting of a single, narrow layer of palisade cells and a broader spongy region, the latter with abundant intercellular spaces and supported by sinuous fibres. Transverse sections through the **midrib** exhibit a U-shaped vascular strand with 1 or 2, often centric, bundles between the arms. Vascular strand in transverse sections through the distal end of the **petiole** likewise U-shaped, but with the ends strongly incurved. Large cluster **crystals** abundant in the parenchymatous tissues.

AXIS

YOUNG STEM

More or less hexagonal when very young. **Hairs** long, unicellular. **Cork** arising in the sub-epidermis; component cells rectangular, with thickened inner tangential walls. **Cortex** parenchymatous, somewhat lacunar. **Pericycle** containing strands of fibres. **Phloem** broad, appearing in transverse sections of relatively old stems as triangular groups with outwardly directed apices, separated by triangular distal ends of the medullary rays; phloem fibres abundant. **Xylem** in the form of a continuous cylinder traversed by uniseriate rays. Vessels relatively infrequent, isolated, in radial rows, or less frequently in small irregular clusters, 30–45 × 25–35 μ in diameter; perforations simple, transverse or slightly oblique. Paratracheal and apotracheal parenchyma fairly abundant. Wood fibres with inconspicuously bordered pits. **Pith** composed of lignified, pitted, parenchymatous cells. **Crystals** abundant; large, solitary, prismatic and cubical types as well as clusters present in the cortex and pith; prisms also occur in the cells of the medullary rays; small prisms and styloids observed in some of the phloem elements. **Secretory elements.** Cells with dense, gum-like contents in some of the parenchymatous cells of the pericycle; a layer of similar cells also observed in the cortex immediately below the cork. Gum-like deposits present in some of the pith cells.

SOLMSIA (Fig. 30 D)

Solmsia consists of trees and shrubs with leathery leaves, characterized by numerous parallel lateral nerves. The genus is described separately because its taxonomic position has been much disputed. It differs from the other members of the Thymelaeaceae, except *Microsemma*, in the absence of intraxylary phloem. Solereder described the genus under Tiliaceae, believing the mucilaginous cells of the leaf epidermis, the triangular phloem strands, and the possession of prismatic crystals to favour its inclusion in that family. It may be noted, however, that all of these characters occur in the Thymelaeaceae as well as the Tiliaceae. Beauvisage (163) found the structure of *Solmsia* to resemble that of *Microsemma*. He records the occurrence of long, unicellular hairs on the leaf, sub-epidermal phellogen in the stem, and cork cells with thickened, tangential walls. The **petiole** (Fig. 30 D), in transverse sections through the distal end, exhibits a deep, crescentic vascular strand with inwardly directed ends, large strands of sclerenchyma being present in the pericyclic region. In this book the genus is retained in the Thymelaeaceae as recommended by Domke (595).

TAXONOMIC NOTES

(i) FROM GENERAL ANATOMY

The taxonomy of the Thymelaeaceae has been fully dealt with in Domke's (595) monograph. In a general way, the greater part of the family is anatomically uniform. There are, however, genera such as *Microsemma* and *Solmsia* which differ somewhat from the remainder of the family, and it is a matter of opinion whether these should be included or not. For this reason they have been described separately in this book.

The taxonomic position of *Microsemma* has been much disputed. Although it has been variously ascribed to the Theaceae and Flacourtiaceae, its anatomical structure is not consistent with its belonging to either of these families. It differs from nearly all of the Thymelaeaceae in the absence of intraxylary phloem, but agrees with some members of the same family in other respects. In particular the stem structure recalls that of *Pimelea*. Beauvisage (163) suggested that the genus should be placed in the Tiliaceae, but the absence of mucilage cavities does not suggest that its affinities lie in this direction. On the whole, it seems most reasonable to follow Domke (595) and include it in the Thymelaeaceae.

In Domke's classification, the Thymelaeaceae are divided into sub-families and tribes based on exomorphic characters. There do not appear to be any anatomical differences corresponding to these sub-divisions, the microscopical variation being of value for the diagnosis of genera rather than tribes or groups of higher rank. In this connexion it is interesting to note that Léandri (1325) regarded the arrangement of the vessels in the xylem of young stems, not more than 1 cm. in diameter, as being of considerable taxonomic value. He attempted to show how the vessel distribution runs parallel to Gilg's subdivisions of the family. Domke (595) has pointed out, however, that there are so many exceptions that, in practice, this reputed parallelism does not exist. Léandri's work is valuable in so far as it enables the genera to be classified in groups according to the vessel distribution, and this facilitates microscopical identification (see p. 1173). The structure of the rather limited material examined at Kew indicates that the 4 types of vessel distribution recognized by Léandri are by no means sharply defined, so it is evidently undesirable to rely too much on this character alone.

There are some genera (see p. 1170) in which intraxylary phloem occurs in the petiole and midrib of the leaf as well as in the stem, and others in which this tissue is confined to the stem. This fact is of considerable diagnostic value, but, as Domke has pointed out, this subdivision, like that based on vessel distribution, does not run parallel to Gilg's classification of the family, in spite of Léandri's attempt to show that it does so.

(ii) FROM WOOD STRUCTURE

Some of the genera form very distinct groups, e.g. *Daphne*, *Dirca*, *Ovidia*, and *Passerina* with their distinctive radial arrangement of the vessels, or the genera with interxylary phloem.

ECONOMIC USES

Mezereum is the bark of *Daphne mezereum* Linn. and *D. laureola* Linn., both indigenous to Britain, and of *D. gnidium* Linn. from southern Europe and Algeria. The bark has been used in medicine, but is not now regarded as important. The tough, flexible bark of *D. mezereum*, which is covered externally by a thin, reddish-brown cork, occurs in long strips or quills. The outer surface is transversely wrinkled, and the inner surface white and silky. Microscopical features include several layers of flattened cork cells; a phelloderm composed of tangentially compressed cells; numerous bundles of very thick-walled fibres, and remnants of sieve tubes in the inner part of the bark; absence of crystals.

The bark of various members of the family is used locally for making ropes, because of the flexible fibres which they contain. Paper is made in Japan from *Edgeworthia gardneri* (Wall.) Meissn. and in China from *Wikstroemia viridiflora* Meissn. *Lagetta lintearia* Lamarck is the Lace-bark tree of Jamaica, the inner part of the bark of which is used to make fancy articles.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Aquilaria, Arthrosolen, Chymococca, Cryptadenia, Dais,* Daphne, *Daphnopsis, Diarthron, Dicranolepis, Dirca,* Drapetes, Edgeworthia, Englerodaphne, Enkleia, Eriosolena, Funifera, Gnidia,* Goodallia, Gyrinops, Gyrinopsis, Hyptiodaphne, Kelleria, Lachnaea, Lagetta,* Lasiadenia, Lasiophyton, Lasiosiphon, Leucosmia, Linodendron, Linostoma, Lophostoma, Microsemma,* Octolepis, Ovidia, Passerina, Peddiea, Pentathymelaea, Phaleria, Pimelea,* Rhamnoneuron, Schoenobiblus, Solmsia, Stellera, Stephanodaphne, Struthiola, Synaptolepis, Thymelaea, Wikstroemia.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Aquilaria, (Dais), Daphne, Daphnopsis, (Diarthron), (Edgeworthia), (Enkleia), Gyrinops, (Lachnaea), Lagetta, (Lasiadenia), Lasiosiphon, (Linostoma), Ovidia, Passerina, Peddiea, Phaleria, (Pimelea), Schoenobiblus, (Stellera), (Synaptolepis), Wikstroemia.

LITERATURE

(i) *On General Anatomy*

Beauvisage **163**, Betts **188**, Choquette **407**, Domke **595**, Foweraker **703**, Galambos **735**, Gilg **766**, Hill **971**, Holm **1006**, Joshi **1197**, Lashevski **1321**, Léandri **1324**, **1325**, **1326**, Lindinger **1374**, Shelton **2086**, Thoday **2249**, Vogl **2338**.

(ii) *On Wood Structure*

Bailey **78**, den Berger **182**, Betts **188**, **189**, Brown, F. B. H. **282**, Burgerstein **310**, Chalk and Chattaway **362**, Giordano **786**, Greguss **2522**, Howard **1088**, Janssonius **1154**, Kanehira **1206**, **1209**, **1213**, Léandri **1325**, Lecomte **1334**, Metcalfe **1496**, Pearson and Brown **1679**, Pfeiffer, H. **1712**, Record **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**, Williams **2430**.

234. GONYSTYLACEAE

(FIG. 283 on p. 1180)

SUMMARY

A small Malayan family of trees belonging to the single genus *Gonystylus*. The information given below concerning the anatomy of the leaf and young stem is based mainly on Solereder's account, as no recent work appears to have been done on this genus. The most noteworthy feature in the young stem is the absence of **intraxylary phloem.** The following are the main features of the wood.

Vessels medium-sized, perforations simple, intervascular pitting minute and pits to parenchyma similar, members of medium length. **Parenchyma** about the vessels and extending laterally in narrow bands. **Rays** usually predominantly uniseriate and almost homogeneous. **Fibres** with numerous bordered pits; of medium length.

LEAF

Dorsiventral. **Hairs** unicellular; glandular types not recorded. **Epidermis** partly composed of mucilaginous cells; according to Solereder, the epidermal cells of certain species of *Gonystylus* are provided with conical proliferations projecting into the mesophyll. Sclerosed epidermal cells also recorded. **Stomata** confined to the lower surface; surrounded by a rosette of rather small epidermal cells in at least certain species. **Secretory cavities** present, sometimes appearing as transparent dots. **Crystals** mostly clustered.

AXIS

YOUNG STEM

Cork arising superficially. **Xylem** in the form of a continuous cylinder traversed by narrow rays. Vessels with simple perforations. **Intraxylary phloem** absent. **Secretory elements.** Cells containing mucilage, and secretory cavities similar to those in the leaf, recorded in the primary cortex. **Crystals** mostly clustered, but solitary types also known to occur.

WOOD (Fig. 283 A–B)

Vessels medium-sized (100–200 μ mean tangential diameter), solitary and in multiples of up to 4 cells and sometimes with numerous irregular clusters locally; with a tendency to an oblique pattern in some material; about 4 per sq. mm. Perforations simple. Intervascular pitting alternate and minute; pits to ray and wood parenchyma similar. Mean member length 0·4–0·6 mm. **Parenchyma** moderately abundant, intermediate between paratracheal and apotracheal bands; about the vessels and extending from them tangentially in bands 1–2 cells wide; sometimes limited to the abaxial sides of the vessels. Occasionally containing a few solitary crystals. Strands mostly of 4 cells. **Rays** predominantly uniseriate, but occasionally biseriate; biseriate rays more common in some material; less than 1 mm. high; 8–13 per mm.; almost homogeneous, but some rays with a single marginal row of square cells; solitary crystals sometimes abundant. **Fibres** with numerous bordered pits in the radial walls, the pits commonly in more than 1 row. Walls of medium thickness. Mean length 1·3–1·6 mm.

TAXONOMIC NOTES

It is a matter of opinion whether *Gonystylus* should be treated as a distinct family or be included in the Thymelaeaceae. In Domke's (595) monograph, the genus is placed with *Amyxa* in a sub-family Gonystyloideae of the Thymelaeaceae. Janssonius (1154) also prefers, although on what appears to be rather slender evidence, to retain *Gonystylus* in the Thymelaeaceae.

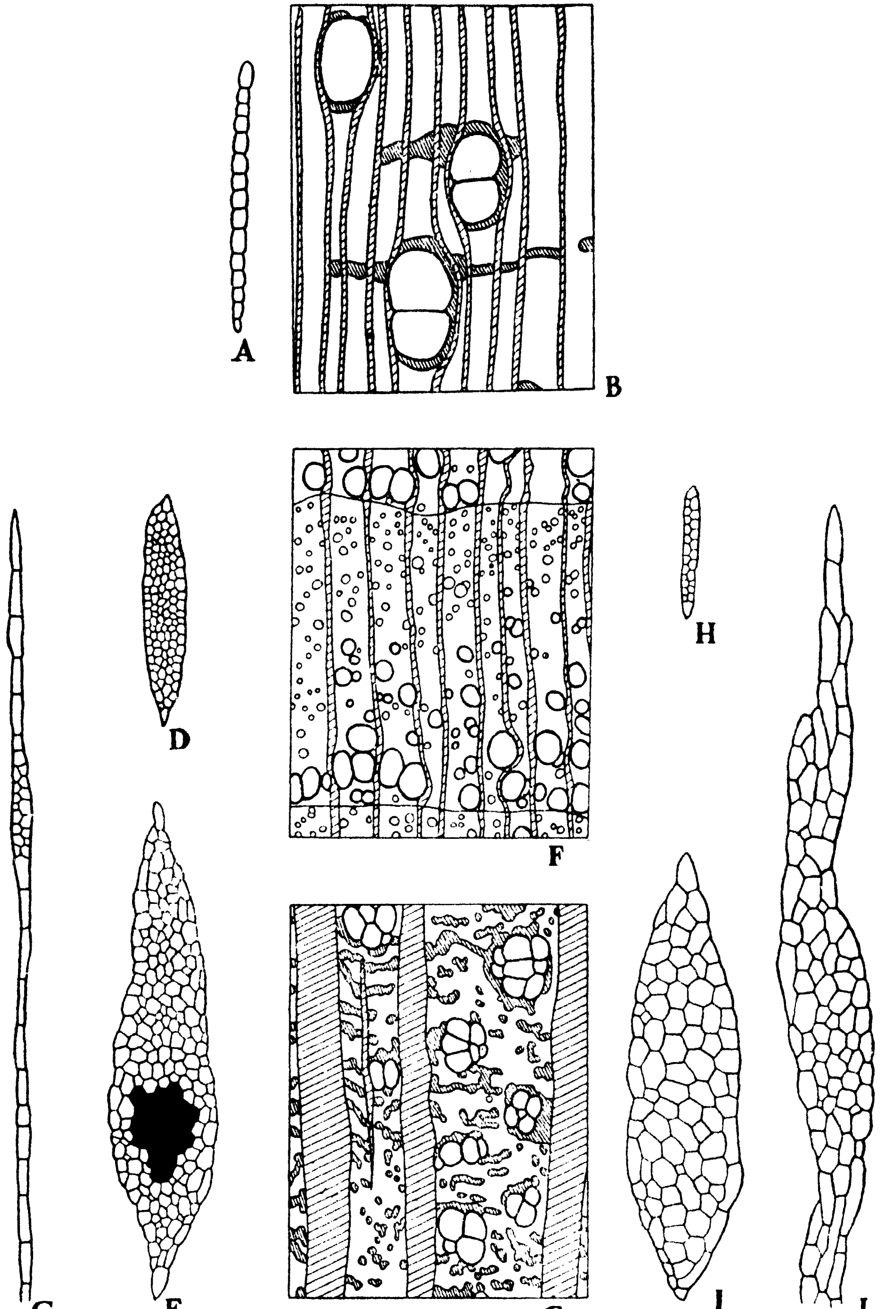


Fig. 283. *GONYSTYLACEAE*, A–B; *ELAEAGNACEAE*, D, F, and H; *LORANTHACEAE*, C, E, G, and I–J

A, *Gonystylus bancanus* Gilg. B, *G. miquelianus* Teijsm. et Binn. C, *Phoradendron crassifolium* Nutt. D, *Elaeagnus angustifolia* Linn. E, *Loranthus falcata* Linn. F, *Hippophae rhamnoides* Linn. G, *Loranthus falcata* Linn. H, *Hippophae salicifolia* D. Don. I, *Elytranthe tetrapetala* Engl. J, *Viscum album* Linn.

Hutchinson (1113) at one time included *Gonystylus* in a separate family amongst the Tiliales, this last order being regarded as in no way related to the Thymelaeales. He has now revised this opinion, however, and considers both the Thymelaeaceae and Gonystylaceae to be more closely related to the Flacourtiaceae and Tiliaceae than he previously supposed. This new view is supported to some extent by general anatomical evidence, which, although incomplete, appears to indicate that the Gonystylaceae, Thymelaeaceae, and Tiliaceae have definite affinities with each other. The occurrence of secretory elements containing mucilage is common to *Gonystylus*, the Tiliaceae, and Thymelaeaceae. The lack of intraxylary phloem serves to distinguish *Gonystylus* from most of the Thymelaeaceae, although it should be noted that this is also absent from *Lagetta*, *Microsemma*, and *Solmsia*, and the rather specialized *Drapetes*.

The evidence from wood anatomy concerning the relationship of *Gonystylus* to the Thymelaeaceae is, however, less conclusive, for though the wood of *Gonystylus* differs from that of all the genera examined of the Thymelaeaceae, all its characters can be matched individually in that family. For example, its rather uncommon type of parenchyma is very similar to that of *Lagetta* (Fig. 282 J and Fig. 283 B), exclusively uniseriate rays occur also in *Aquillaria* (though those of the latter are not homogeneous), and minute, alternate intervascular and ray-vessel pitting is characteristic of the Thymelaeaceae. Affinity with the Tiliaceae is much more questionable. Janssonius (1154), as mentioned above, prefers the inclusion of *Gonystylus* in the Thymelaeaceae rather than its treatment as a separate family.

GENUS DESCRIBED

Gonystylus.

LITERATURE

(i) *On General Anatomy*
Domke **595**, Hutchinson **1113**.

(ii) *On Wood Structure*
Desch **574**, Janssonius **1154**, Record **1851**.

235. PENAEACEAE

(FIG. 284 on p. 1182)

SUMMARY

A family of small, ericoid shrubs confined to South Africa. The **mesophyll** of the thick leaves frequently contains fibrous elements, some of which are relatively thin-walled and resemble spirally thickened tracheids. **Hairs** are infrequent, mostly simple and unicellular when present. **Stomata** ranunculaceous; present on both surfaces or confined to the lower side of the leaf. The most noteworthy feature of the axis is the ubiquitous occurrence of **intraxylary phloem**.. The **xylem** includes grouped or isolated vessels 22–40 μ in diameter, with simple perforations. The wood fibres are provided with bordered pits.

LEAF

Usually dorsiventral, but sometimes isobilateral or centric. **Hairs** rare; generally short, simple, and unicellular, when present. **Cuticle** granular or striate in some species; forming well-marked external pegs in *Endonema retzioides* Sond. Cells of the **epidermis** frequently filled with brown, tanniniferous contents; outer walls often thick. **Stomata** present on both surfaces in species of *Brachysiphon*, *Penaea* (a few species), *Sarcocolla*; confined to the lower side in most species of *Endonema*, *Glischrocolla*, *Penaea*; ranunculaceous in species of *Endonema*, *Penaea*, *Sarcocolla*. Peg-like projections extend into the cavities of the cells adjoining the stomata in *Penaea myrtoides* Linn. (Fig. 284 F) and *Sarcocolla fucata* Endl. **Mesophyll** including short palisade cells; spongy portion never very lacunar. Sclerenchymatous fibres, with or without spiral markings (Fig. 284 C), present in the mesophyll; both kinds recorded in species of *Endonema*, *Penaea*, *Sarcocolla*; always with spiral markings in *Glischrocolla*, but without them in *Brachysiphon*. Only clustered **crystals** recorded.

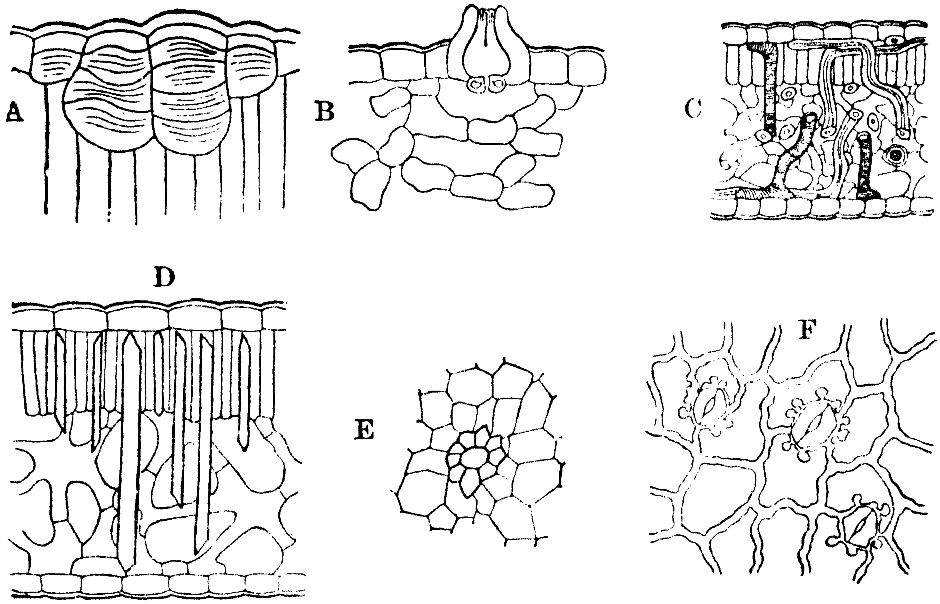


FIG. 284. *THYMELAEACEAE*, A, B, D, E; *PENAEACEAE*, C, F

A, Mucilaginous epidermal cells in the leaf of *Arthrosolen somalensis* Franch. B and E, Stomata enclosed in receptacles: B, in transverse section; E, surface-view. C, Transverse section through the leaf of '*Penaea mucronata*'. D, Transverse section of the leaf of *Dicranolepis* sp. with styloids. F, Surface-view of the epidermis on the lower side of the leaf of *Penaea myrtoides* L. f., seen from within.—A and D after Van Tieghem, B and E after Supprian, C after Van Tieghem, F by Solereder.

AXIS

STEM

Cork arising in the pericycle in *Penaea mucronata* Linn.; composed of cells with thin and thick walls, the 2 types sometimes arranged in alternating layers. Thin-walled cork cells said to be unsuberized. Primary **cortex** usually collenchymatous; sometimes including a few stone cells. A large-celled **endodermis** with casparian thickenings said to occur in *Penaea mucronata.* Outer part of the **phloem** often collenchymatous; including chambered fibres containing clustered crystals. Small **vascular bundles** from the leaves said to lie in the 4 angles of the stem in species of *Endonema.* **Xylem** in the form of a continuous cylinder traversed by narrow rays; including isolated and grouped vessels about 22–40 μ in diameter and provided with simple perforations; scanty parenchyma; a groundwork of thick-walled fibres with bordered pits. **Intraxylary phloem** present in all members of the family; usually unaccompanied by sclerenchymatous elements apart from a few rod-cells at its inner margin. **Pith** frequently including stone cells.

GENERA DESCRIBED

Brachysiphon, Endonema, Glischrocolla, Penaea, Sarcocolla.

In the absence of recent information, or of material for examination, the above description has been based on Solereder's account.

236. GEISSOLOMATACEAE

SUMMARY

This family is represented only by the single South African species *Geissoloma marginatum* Juss. which is a low shrub.

LEAF

Dorsiventral, with a swollen margin composed of specially tall epidermal cells. **Epidermis,** on both surfaces, including mucilaginous cells. Epidermal cells, on the upper side, provided with strongly thickened outer walls and well-marked cuticular pegs. **Stomata** confined to the lower surface. **Mesophyll,** unlike that of the Penaeaceae, including no sclerenchymatous fibres. Cluster **crystals** present in the mesophyll.

AXIS

STEM

Cork arising in the outer part of the primary cortex; component cells with wide lumina. Primary **cortex** including stone cells, also with wide lumina. **Pericycle** containing a composite and continuous ring of sclerenchyma. **Xylem** including scattered vessels with a mean diameter of 25 μ, and scalariform perforation plates with many bars; large, simple vessel-ray pits; fibres with bordered pits; rays 1–3 cells wide, composed of somewhat vertically elongated cells. Clustered and solitary **crystals** recorded in the primary cortex, and solitary types in the phloem as well.

TAXONOMIC NOTES

Geissoloma was included in the closely related Penaeaceae in the Bentham and Hooker system. Although otherwise anatomically alike in several respects, it is interesting to note that *Geissoloma* differs from the Penaeaceae in the absence of sclerenchymatous fibres from the mesophyll of the leaf.

GENUS DESCRIBED

Geissoloma.

In the absence of recent information, or of material for examination, the above description has been based on Solereder's account.

237. ELAEAGNACEAE

(FIG. 283 on p. 1180; FIG. 285 on p. 1186)

SUMMARY

(i) GENERAL

A temperate and tropical family of shrubs and small trees, the exterior of whose leaves and young branches is covered with stellate and peltate **hairs,** which are often present in sufficient numbers to give these organs a silvery or brown appearance. The anatomy of the family has been described in very great detail by Servettaz (2082), the structure of all parts of the plants in most members of the family having been examined. The **stomata,** which are confined to the lower surface of the leaf, are ranunculaceous. **Crystals** are secreted in the form of long or short needles as well as of crystal-sand, rhombohedral tablets, octahedra, and prisms, but of these the various types of acicular crystals and crystal-sand are the most characteristic. Typical cluster crystals have been recorded only in the young roots of *Shepherdia canadensis* Nutt. The types of crystal are more reliable for diagnostic purposes than is the frequency, but both type and frequency are liable to vary within a species. **Tanniniferous substances** are very abundant in the family.

(ii) WOOD

Vessels small, solitary, ring-porous, with simple perforations, intervascular pitting rather small and pits to parenchyma similar, members very short. **Parenchyma** diffuse, sometimes very sparse. **Rays** up to 3–20 cells wide, heterogeneous to almost homogeneous, with rather few uniseriates. **Fibres** with conspicuously bordered pits, moderately to very short. Traumatic, vertical **intercellular canals** occasionally present.

LEAF

Typically dorsiventral, e.g. in *Shepherdia canadensis* Nutt., but the lowest layer of mesophyll tending to be palisade-like in *Hippophaë rhamnoides* Linn. Surface of all species covered by characteristic stellate and peltate **hairs** (Fig. 285 G), usually with short but occasionally longer stalks. The mode of development of these hairs has been described by Cooper (459), Sakisaka and Suehiro (1982), and Servettaz (2082). **Stomata** confined to the lower surface; only ranunculaceous types recorded. Vascular bundles of the **veins** not accompanied by sclerenchyma. **Petiole** (Fig. 285 H, J), in transverse sections through the distal end, exhibiting a more or less open vascular arc in species of *Elaeagnus* with deciduous leaves, as well as in *Hippophaë* and *Shepherdia* (Fig. 285 J); vascular structure at first similar in evergreen species of *Elaeagnus*, but the ends of the arc become incurved and finally united to form a cylinder in mature leaves (Fig. 285 H). Vascular strand remaining open at the base of the petiole even in those species of *Elaeagnus* where it becomes closed at the distal end. Petiolar vascular strand not accompanied by pericyclic sclerenchyma in *Hippophaë* and *Shepherdia*, but fibres present in this region in some species of *Elaeagnus*, the amount of sclerenchyma present in any one species partly depending on the maturity of the specimen and the nature of the habitat in which grown. **Crystals** mostly in the form of long and short needles or crystal-sand, but the other types of crystal mentioned in the 'Summary' on p. 1184 also occur. Crystals in the leaf mostly in the palisade cells and in the region of the veins; less numerous but more varied in type in the petiole.

AXIS

YOUNG STEM (Fig. 285 I)

Cork arising precociously in the sub-epidermis of *Hippophaë* and *Shepherdia*, but originating more tardily in the epidermis in *Elaeagnus* (Fig. 285 I); component cells usually somewhat flattened and provided with wide lumina and thin walls. Primary **cortex** usually somewhat spongy. **Pericycle** including an almost continuous zone of sclerenchyma when sufficiently young, but strands of fibres becoming more widely spaced in older material of *Elaeagnus*, *Hippophaë*, and *Shepherdia*. Stone cells (sometimes crystalliferous) also arising in the zone of pericyclic sclerenchyma in *Elaeagnus* (not in the other genera), but their presence or absence stated by Servettaz (2082) to vary with the habitat in some species, their occurrence being more constant in xerophytes. **Phloem** becoming stratified into fibrous and soft portions in *Elaeagnus*, *Hippophaë*, and *Shepherdia*; stone cells, similar to those in the pericycle, also occur in the phloem of *Elaeagnus*. **Xylem** in the form of a continuous cylinder traversed by narrow rays; exhibiting well-defined annual rings in *Hippophaë*, but those of *Shepherdia* less distinct. Three types of xylem recognized in *Elaeagnus* by Servettaz (2082). (i) Vessels scattered throughout each growth ring in evergreen species such as *E. glabra* Thunb. and *E. pungens* Thunb. (ii) Vessels in early wood arranged in several very obvious concentric circles in deciduous species such as *E. umbellata* Thunb. (iii) Large early wood vessels arranged in arcs rather than circles in '*E. thunbergii*'. Vessels with simple perforations. Rays in *Hippophaë* very narrow and numerous, remaining wholly uniseriate during the first 2 years or so, before becoming broader; those of *Elaeagnus* 1–4 cells wide in young stems but then becoming broader (see under 'Wood').

Pith. Central and perimedullary portions frequently rather sharply contrasted, the component cells at the periphery being smaller and with thicker walls than those at the centre of the pith. Central part consisting of thin-walled, spongy tissue in *Hippophaë*; composed of homogeneous, thin-walled tissue in one group of species of *Elaeagnus*, and of homogeneous but sclerosed cells in a second group of species in the same genus, and of a heterogeneous tissue of thin- and thick-walled cells in a third group of species. **Crystals,** of the same kinds as described above under 'Summary', occur in the unlignified tissues; e.g. according to Servettaz (2082) crystal-sand and short needles in the phloem of *Elaeagnus*; crystal-sand in the cortex of *Hippophaë*; prismatic crystals, crystal-sand and quadrangular tablets in the cortex of *Elaeagnus indica* Serv. and '*E. thunbergii*'. Crystals also observed by Servettaz in the pith of *Hippophaë*, but not in the corresponding position in *Shepherdia* or any of the 20 species of *Elaeagnus* he examined. The quantity of crystals present is stated by Servettaz to vary not only in individual specimens of a single species but even at different levels in a single internode. The same author found the form rather than the distribution of crystals to be of taxonomic importance. Variously arranged **tanniniferous cells** present in the pith and other soft tissues.

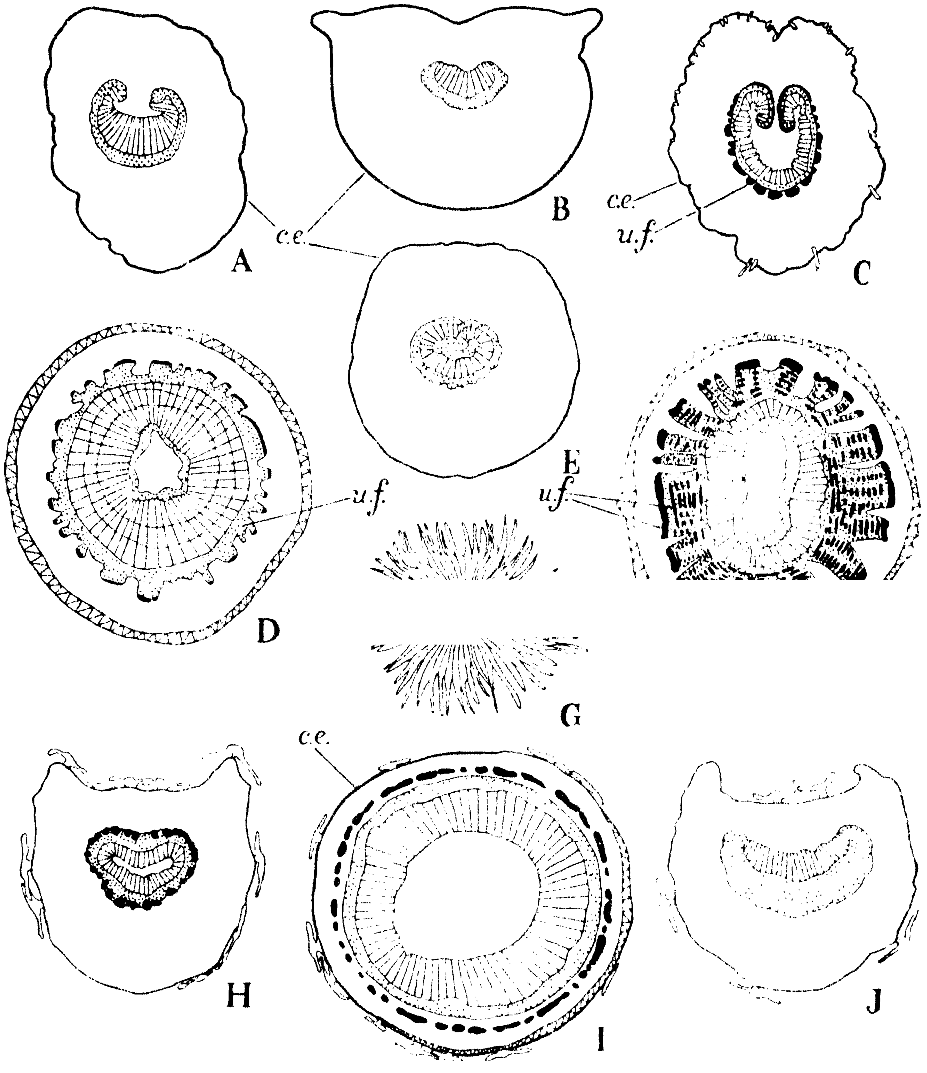


FIG. 285. *THYMELAEACEAE*, A–F; *ELAEAGNACEAE*, G–J

A, *Dais cotonifolia* Linn. Petiole × 15. B, *Daphne* sp. Petiole × 19. C, *Microsemma salicifolia* Labill. Petiole × 13. D, *Daphne laureola* Linn. Stem × 8. E, *Lagetta lintearia* Lam. Petiole × 12. F, *L. lintearia* Lam. Stem × 11. G, *Elaeagnus* sp. Hair × 56. H, *E. umbellata* Thunb. Petiole × 26. I, *E. umbellata* Thunb. Stem × 18. J, *Shepherdia argentea* Nutt. Petiole × 39.

c.e. Cutinized epidermis. *u.f.* Unlignified fibres.

WOOD (Fig. 283 D, F, and H)

Vessels small (less than 100 μ mean tangential diameter), the late wood vessels usually extremely small; almost exclusively solitary; 30–200 per sq. mm.; ring-porous; spiral thickening observed in *Hippophaë rhamnoides* L. and reported in some species of *Elaeagnus* (1206) and *Shepherdia* (1851). Perforations simple. Intervascular pitting alternate, rather small; pits to ray and wood parenchyma similar. Solid deposits common in *Hippophaë* and *Shepherdia*. Mean member length about 0·25 mm. **Parenchyma** apotracheal, as scattered cells, moderately abundant and tending to form short uniseriate bands in *Elaeagnus*, very sparse in some species of *Hippophaë* and *Shepherdia*; strands usually of 2 cells; sometimes tending to be storied if sufficiently abundant. **Rays** up to 3–4 cells wide in *Hippophaë* and *Shepherdia*, 5–20 cells wide in *Elaeagnus*; less than 1 mm. high, except in some species of *Elaeagnus* (1206); uniseriates low, rather few, usually composed of square and procumbent cells, but sometimes composed of square to upright cells only; 6–11 rays per mm.; heterogeneous (Kribs's Type II A), with 1–3 marginal rows of square or upright cells, to almost homogeneous in some species of *Elaeagnus*. Storied in *Hippophaë salicifolia* D. Don. **Fibres** with conspicuously bordered pits, equally abundant in both radial and tangential walls in *Elaeagnus*, but mostly in the radial walls in *Hippophaë*. Storied in *Hippophaë salicifolia*. Mean length about 0·5–0·9 mm. Spiral thickening reported by Kanehira (1209) in *Elaeagnus multiflora* Thunb. **Intercellular canals** of the vertical traumatic type reported (1817) in *Elaeagnus pungens* Thunb. and *E. umbellata* Thunb.

ROOT

Servettaz (2082) distinguishes between the roots of *Hippophaë* and *Shepherdia* on the one hand and those of *Elaeagnus* on the other by the following characters.

Endodermis provided with casparian thickenings in the upper part of the hypocotyl. Principal roots of the seedling diarch. Medullary rays mostly uniseriate, but sometimes partly biseriate. Root nodules arising by dichotomous branching of the rootlets. Mycorrhiza present in the cortex of the rootlets—*Hippophaë* and *Shepherdia*.

Endodermis devoid of casparian thickenings at the base of the hypocotyl. Roots diarch-tetrarch. Medullary rays partly 3–5 cells wide. Root nodules arising by di- or trichotomous divisions of the roots—*Elaeagnus*.

According to Spratt (2176) the root tubercles of *Elaeagnus* are produced after infection with a nitrogen-fixing bacterium. The bacteria in the root nodules of *Elaeagnus* have been studied more recently by Borm (238), who showed that the endophytic bacteria at first infect a definite region of the gall, causing enlargement of the cells. The nucleus of the infected cell is stated to become amoeboid, whilst the infecting bacteria at first multiply until the cell is completely filled, but subsequently become decomposed by phagocytic action and are then digested.

TAXONOMIC NOTES

Servettaz (2082) points out that, from the anatomical standpoint, *Hippophaë* and *Shepherdia* are more like one another than is either genus to *Elaeagnus*.

He also concluded, on general rather than on anatomical grounds, that the affinities of the Elaeagnaceae lie with those of the Proteaceae, Penaeaceae, and Thymelaeaceae.

GENERA DESCRIBED (for general anatomy and wood structure)

Elaeagnus,* Hippophaë,* Shepherdia.*

* Represented in the Kew slide collection.

LITERATURE

(i) *On General Anatomy*

Borm **238**, Cooper **459**, Sakisaka and Suehiro **1982**, Servettaz **2082**, Spratt **2176**.

(ii) *On Wood Structure*

Greguss **2522**, Kanehira **1206**, **1209**, Nicoloff **1593**, Record **1800**, **1817**, **1851**, Yamabayashi **2478**.

238. LORANTHACEAE

(FIG. 283 on p. 1180; FIG. 286 on p. 1190; FIG. 287 on p. 1192)

SUMMARY

(i) GENERAL

Only a few members of the family, such as *Atkinsonia*, *Gaiadendron*, and *Nuytsia*, have roots that penetrate the ground, and even in these plants there is reason to believe, according to Engler and Krause (646), that the roots become united with those of other plants in the vicinity. The remainder of the family consists of somewhat woody plants which grow as semi-parasites on the aerial parts of others, mostly belonging to the Dicotyledons. The semi-parasitic species derive their mineral nutriment from the host plants through absorbing organs of various kinds known as haustoria, whilst normal carbon assimilation takes place in the somewhat leathery leaves, and frequently in the stems, which also contain chlorophyll. Some species such as *Arceuthobium minutissimum* Hook. f. are very much reduced in size. Many members of the family occur in tropical and sub-tropical regions, but a few, including the familiar Mistletoe (*Viscum album* Linn.), occur in temperate countries. The structure and biology of *V. album* have been very exhaustively described by von Tubeuf (2287).

The **hairs** are often complex, various candelabra types being common. The distribution of the mostly rubiaceous **stomata** varies according to the nature of the leaf, the whole surface being perforated when the mesophyll is isobilateral or composed wholly of isodiametric cells. Stomata on the surface of assimilatory stems are often transversely orientated in relation to the longitudinal axis. The **mesophyll** is dorsiventral, isobilateral, or wholly composed of isodiametric cells in different species. Groups of silicified cells have been recorded in the mesophyll in some genera, while stone cells also occur in the same region, as well as in the cortex and pith of the axis. The **cork** arises superficially in the stem, but is sometimes replaced by a 'cuticular epithelium'. The **pericycle** contains isolated strands of fibres. The **vascular system** of the stem is generally normal, but transverse sections of the young axis of *Arceuthobium oxycedri* (DC.) Marsch. Bieb. exhibit 2 opposite pairs of vascular bundles. In young stems of *Nuytsia floribunda* (Labill.) R. Br. **interxylary phloem** is to be found, and, in older stems of the same species, concentric zones of xylem and phloem are laid down. A somewhat similar type of structure has also been recorded in an unidentified species of *Loranthus* from the Cameroons. **Crystals** secreted, especially in old tissues, in solitary and clustered forms. **Tanniniferous cells** present in the parenchymatous tissues, particularly of the Loranthoideae.

(ii) WOOD

Vessels very small, very variable in arrangement, spiral thickening occasionally present, perforations simple, intervascular pitting alternate, pits to parenchyma sometimes large and simple, members moderately to extremely short. **Parenchyma** often abundant, scattered or in short, uniseriate lines and about the pores, typically storied and consisting entirely of fusiform cells. **Rays** 1–4 cells wide or broad (up to 12 cells wide) and without uniseriates, more than 1 mm. high, slightly to markedly heterogeneous. **Fibres** with simple or distinctly bordered pits, very to extremely short.

LEAF

Dorsiventral, isobilateral, or with the lamina mainly composed of isodiametric cells, the last type recorded, for example, in *Loranthus europaeus* Jacq. and *Tupeia antarctica* (Forst.) Cham. Mesophyll of the biennial leaves of *Viscum album* Linn., consisting of isodiametric cells during the first year, but a single layer of palisade tissue developing towards both surfaces in the second year. **Hairs** (Fig. 286) infrequent or sometimes absent, when present somewhat complex, the simplest types being uniseriate, with lateral processes arising from the upper ends of each of the cells, e.g. in *Loranthus rufescens* DC. (Fig. 286 B). Candelabra-hairs (Fig. 286 C–E) present in certain species of *Loranthus* as well as in *Notothixos*. A dense tomentum of stellate hairs recorded by Wood (2458) in *Loranthus quandang* Lindl. Glandular hairs unknown. **Epidermis** composed of cells with very much thickened outer walls; anticlinal walls of the epidermal cells from both surfaces seen to be rather thick and straight in *L. tetrapetalus* Linn. (syn. *Elytranthe tetrapetala* Engl.), *Phoradendron crassifolium* Nutt., and *Viscum articulatum* Burm. when examined at Kew. **Stomata** present on both surfaces of leaves with isobilateral or homogeneous structure, but more frequent on, or confined to, the lower side of dorsiventral leaves; rubiaceous types recorded in species of *Antidaphne*, *Arceuthobium*, *Lepidoceras*, *Nuytsia*, *Tupeia*, *Viscum*; usually not appreciably sunken below the level of the epidermis; irregularly orientated in most species, but arranged transversely to the longitudinal axis of the leaf in *Nuytsia floribunda* R. Br. Groups of silicified cells, often united in the form of a sphere, reported by Solereder to occur in the **mesophyll**, particularly in association with the vascular bundles, in species of *Loranthus*, *Phoradendron*, '*Stachyphyllum*', *Viscum*. Strongly thickened stone cells, which are often branched, also reported by Engler and Krause (646) to occur in the mesophyll of species with persistent leaves; solitary crystals frequently present in these elements.

Vascular bundles of the **veins** accompanied, in some species, by strongly developed arcs of sclerenchyma, or by an arc of collenchyma, e.g. in species of *Loranthus*, *Tupeia*, *Viscum*. Vessels frequently ending in enlarged terminal tracheids; somewhat similar elements also occur in association with the vascular bundles in species of *Loranthus* and *Nuytsia* or as independent storage tracheids in the mesophyll of *Loranthus*. **Petiole** (Fig. 287 A, C, E), in transverse sections through the distal end, exhibiting an arc of closely placed bundles in *L. tetrapetalus* Linn. (Fig. 287 C) (syn. *Elytranthe tetrapetala* Engl.); bundles also in an arc, but more widely spaced and each supported on both the adaxial and abaxial sides by strands of thick-walled fibres, in *Phoradendron crassifolium* Nutt. (Fig. 287 E); similar but with smaller caps of fibres in *Viscum album* Linn. (Fig. 287 A). **Mucilage canals,** connected with similar structures in the axis, extend into the midrib of *Nuytsia floribunda*.

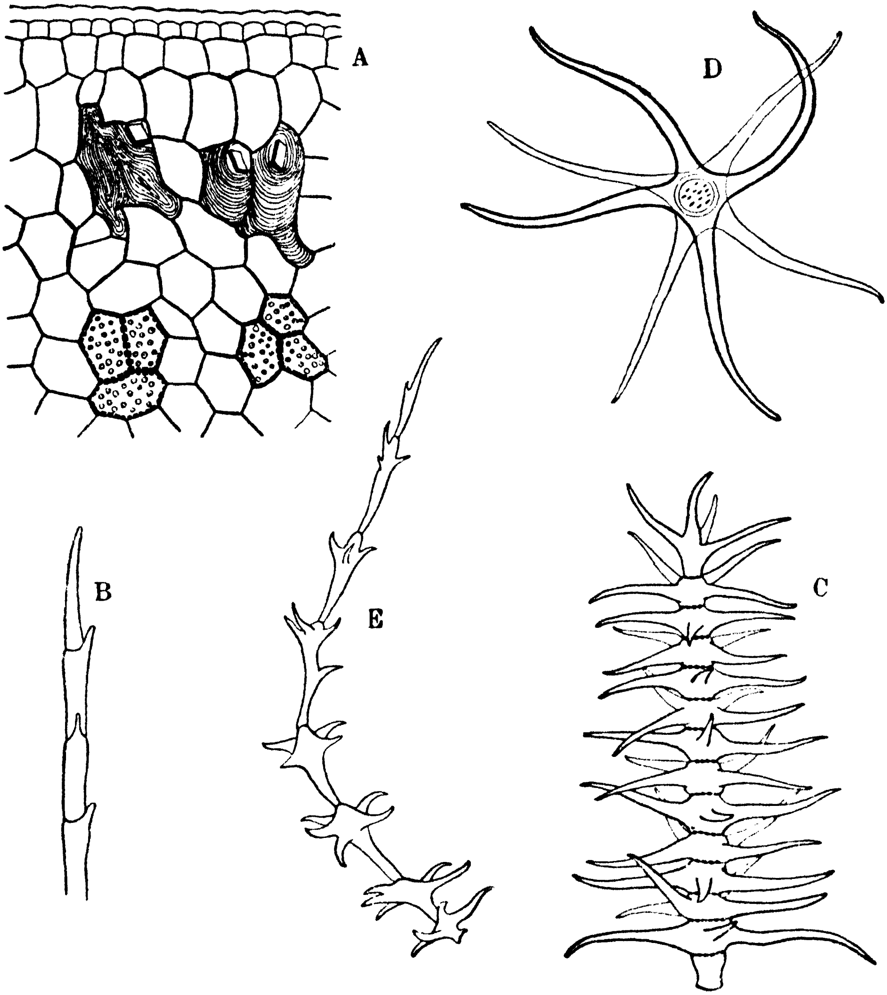


FIG. 286. *LORANTHACEAE*

A, Portion of a transverse section of the leaf of *Loranthus ferrugineus* Roxb. B–E, Trichomes: B and E, *L. rufescens* DC.; C and D, *L. ferrugineus*.—By Solereder.

Crystals occur as clusters or in solitary forms, the latter recorded particularly in the stone cells in the mesophyll (Fig. 286 A).

AXIS

STEM (Fig. 287 B, D, F)

Cork arising superficially in species of *Loranthus*, *Nuytsia*, *Phoradendron* (Fig. 287 D), *Tupeia*; absent from, but gradually replaced by, a cuticular epithelium, consisting of the epidermis and outer cells of the cortex whose walls become thickened, in species of *Arceuthobium* (Fig. 287 B), *Dendrophthora*, *Notothixos*, *Phoradendron*, *Viscum* (Fig. 287 F). **Stomata** arranged transversely to the longitudinal axis of the branch in *Antidaphne*, *Arceuthobium*, *Lepidoceras*, *Loranthus*, *Nuytsia*, *Viscum*. Primary **cortex** frequently developed as assimilatory tissue (Fig. 287 F), the other part sometimes palisade-like, e.g. in *Nuytsia*. Stone cells, often branched and sometimes containing solitary crystals, not uncommon in the cortex in species of *Arceuthobium*, *Loranthus*, *Phoradendron*, *Tupeia*, *Viscum*. Isolated strands of fibres recorded in the region of the **pericycle** in species of *Antidaphne*, *Arceuthobium*, *Gaiadendron*, *Lepidoceras*, *Loranthus*, *Nuytsia*, *Phoradendron*, *Tupeia*, *Viscum* (Fig. 287 F).

Phloem stated by Engler and Krause (646) to be devoid of sclerenchyma; clusters of stone cells (sometimes crystalliferous) noted at Kew, however, in the phloem of *Phoradendron crassifolium* Nutt., *Viscum articulatum* Burm., and *V. capense* Thunb. **Xylem** described by the same authors as being in the form of a more or less continuous cylinder traversed by rays 1–3 cells wide in *Lepidoceras*, *Loranthus*, *Phrygilanthus*, *Phthirusa*, *Struthanthus*, and by broader rays in *Loranthus europaeus* Jacq. and several species of *Viscum*. Xylem, in material examined at Kew, in the form of radiating plates separated by broad, unlignified, medullary rays in *Arceuthobium oxycedri* (DC.) Marsch. Bieb. (Fig. 287 B); similar but with the medullary rays consisting of lignified, pitted cells in *Viscum capense* Thunb. Xylem more continuous but traversed by fairly broad rays in *Loranthus tetrapetalus* Linn. (syn. *Elytranthe tetrapetala* Engl.), and by broader but wholly lignified rays in *Phoradendron flavescens* (Pursh.) Nutt., and by much narrower rays in *Phoradendron crassifolium* Nutt. (Fig. 287 D), *Viscum album* Linn. (Fig. 287 F), and *V. articulatum* Burm. A flattened circle of widely spaced vascular bundles, each supported both towards the exterior and centre of the stem by strands of fibres, seen in the cladode of *V. articulatum*. Protoxylem groups in the stem supported, on the side towards the pith, by strands of thick-walled fibres in *Phoradendron flavescens*, *Viscum articulatum*, and *V. capense*. Vessels with simple perforations. For further particulars see 'Wood'.

Pith parenchymatous in *Viscum album* and in young branches of *Loranthus europaeus*; composed partly or wholly of lignified, pitted cells in *Phoradendron crassifolium*, *P. flavescens*, and *Viscum capense*. **Mucilage canals,** lined with epithelium, present in the pith and, in older material, the phloem of *Nuytsia floribunda* (Labill.) R. Br. Canals in the pith of this species consisting of one at the centre and others at the periphery opposite the larger vascular bundles. **Secretory canals** in the cortex and pith also noted at Kew in *Phoradendron crassifolium* Nutt. **Tanniniferous cells** fairly common, noted at Kew in species of *Arceuthobium* and *Loranthus*. **Crystals** secreted in clustered and solitary forms, the latter recorded particularly in the cortical stone cells.

Cluster crystals noted at Kew in the soft tissues of species of *Arceuthobium*, *Phorodendron*, and *Viscum*; sphaero- and cluster crystals abundant in the ground-tissue of the cladode of *V. articulatum*.

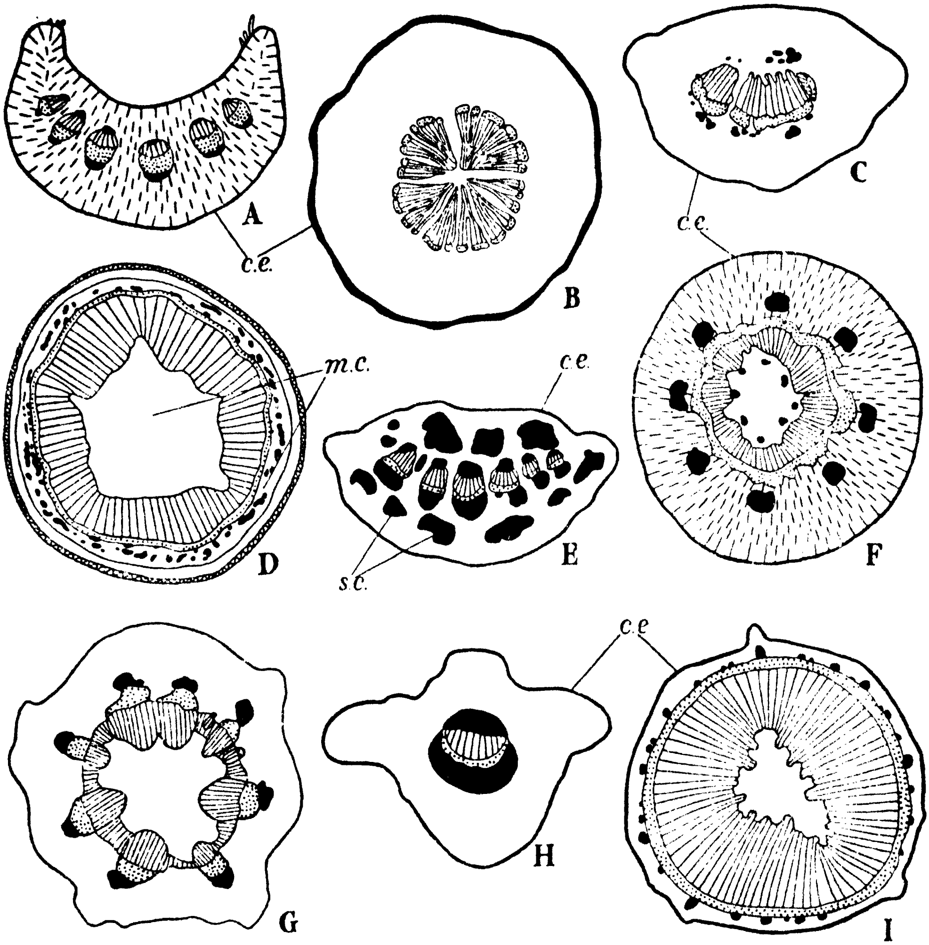


Fig. 287. *LORANTHACEAE*, A–F; *SANTALACEAE*, G–I

A, ***Viscum album*** Linn. Petiole × 12. B, *Arceuthobium oxycedri* Marsch. Bieb. Stem × 6. C, ***Loranthus tetrapetalus*** Linn. Petiole × 25. D, *Phoradendron crassifolium* Nutt. Stem × 7. E, *P. crassifolium* Nutt. Petiole × 17. F, *Viscum album* Linn. Stem × 12. G, *Thesium humifusum* DC. Stem × 34. H, *Osyris wightiana* Wall. Petiole × 21. I, *O. abyssinica* Hochst. Stem × 8.

c.e. Cutinized epidermis. *m.c.* Mucilage canals present in the regions indicated. *s.c.* Stone cells.

Wood (Fig. 283 c, e, g, and i–j)

Vessels extremely small (less than 25 μ mean tangential diameter) in *Elytranthe*, *Phoradendron*, and *Viscum*, slightly larger than 50 μ in some species of *Loranthus*; very variable in arrangement, in small discrete clusters or multiples in *Loranthus* (Fig. 283 g), in clusters and short tangential groups or rows in *Elytranthe tetrapetala* Engl. and *Gaiadendron tagua* (H. B. et K.) D. Don (1853), mostly in radial multiples, which are often of 4 or more cells, in *Phoradendron crassifolium* Nutt. and *Viscum articulatum* Burm., and in long irregular radial masses between the rays in *Viscum* and *Phoradendron flavescens* (Pursh.) Nutt. With spiral thickening in *Loranthus europaeus* Jacq. (2158) and *Phoradendron flavescens*. Perforations simple. Intervascular pitting alternate and small to moderately large, sometimes with coalescent apertures. Pits to parenchyma mostly similar to the intervascular pitting, but usually with some larger and simple pits, particularly in *Loranthus falcata* L. f., in which these pits resemble small perforations in the lateral walls. Mean member length typically 0·07–0·10 mm. (e.g. in *Loranthus falcata* and *Tupeia*) but up to 0·3 mm. in *Phoradendron crassifolium* Nutt. **Parenchyma** typically predominantly apotracheal, as scattered cells or numerous, short, uniseriate bands; often with some cells about the vessels in addition; containing numerous solitary crystals in *Viscum articulatum* Burm. and druses in *V. capense* Thunb.; usually consisting almost entirely of fusiform cells and storied, but with strands of up to 8 cells and not storied in *Phoradendron crassifolium*. **Rays** 2–12 cells wide, largest in some species of *Elytranthe*, *Loranthus*, and *Phoradendron*, not more than 3 cells wide, according to Solereder (quoting Engler) in most species of *Lepidoceras*, *Loranthus*, *Phrygilanthus*, *Phthirusa*, *Struthanthus*, and *Viscum*; typically more than 1 mm. high and often very high; uniseriates rare in the species with large rays; usually about 5 rays per mm. or fewer; sometimes composed entirely of square to upright cells, e.g. in *Phoradendron flavescens*, sometimes of irregularly mixed procumbent and square to upright cells, e.g. in *Viscum album* L., and with central procumbent cells and marginal rows of upright cells in *Phoradendron crassifolium*; only slightly heterogeneous, according to Record (1853), in *Gaiadendron*. Containing druses in *Viscum capense* and with groups of sclerosed cells, each usually containing a single crystal, in *Loranthus falcata* (Fig. 283 E), *L. pentandrus* L., and *Viscum capense*. **Fibres** with distinctly bordered pits observed in *Loranthus falcata* (but not in *L. pentandrus*) and reported (1853, 2158) in *Gaiadendron*, *Loranthus pentapetalus* Roxb., *Nuytsia*, and *Tupeia*; with simple pits in the other genera. Walls typically thick, but moderately thin in *Phoradendron crassifolium* and sometimes very thick, e.g. in *P. flavescens* and *Viscum*. Mean length 0·4–0·6 mm. (*Tupeia* and *Loranthus*).

ANOMALOUS STRUCTURE

Transverse sections of the stem of *Arceuthobium oxycedri* (DC.) Marsch. Bieb. exhibit two opposite pairs of bundles, one pair being more strongly developed than the other. Bands of **interxylary phloem** present in young branches of *Nuytsia floribunda* (Labill.) R. Br.; older stems of the same species exhibiting secondary rings of growth, the xylem being traversed by concentric layers of thin-walled tissue, consisting chiefly of large parenchymatous cells, but including mucilage canals as well as small groups of phloem and traversed by broad lignified rays. Concentric rings of vascular bundles also recorded in a species of *Loranthus* from the Cameroons.

UNION WITH THE HOST

The various types of union between members of the Loranthaceae and their host plants have been the object of numerous investigations, and the subject has been fully summarized by Engler and Krause (646). In some members of the family, particularly those from tropical or sub-tropical regions, root-like structures grow along the surface of the host plant, to which they become attached at intervals by absorbing-organs termed haustoria. These structures, which contain tracheids but no sieve tubes, become very intimately connected with the vessels of the host, from which nutriment is directly absorbed. Species, such as *Viscum album* Linn., from temperate regions are provided with root-like structures that are embedded in the cortex of the host, and from these short haustoria arise and serve as direct connexions to the xylem of the host. The parasites sometimes induce considerable modification and hypertrophy of the host tissues, whilst the base of the parasite itself often becomes enlarged. In some instances, after the parasite has decayed, the swollen and ruptured host tissues assume a somewhat radiate structure and are then sometimes termed 'Wood flowers'. They are known as 'Rosa de Palo' in Mexico and as 'Rosa de madera' in Guatemala.

Various opinions have been expressed concerning the morphological nature of the haustorium. McLuckie (1471) concluded that the haustorial system of *Loranthus celastroides* Sieb. represents root tissue, developed from the primary root of the seedling, which, at least in this species, is very sensitive to gravity. McLuckie also found that the haustoria penetrate the host partly by mechanical pressure and partly by enzyme action, the disorganized host tissues providing some of the nourishment for the parasite before the latter becomes firmly established. *L. celastroides* is sometimes prevented from becoming well established on its host by a tissue barrier formed from a phellogen. Most Loranthaceae are parasitic on other Dicotyledons, many of the species being able to live on a wide range of unrelated hosts. A few are parasitic on Monocotyledons, the parasitism of a species of *Loranthus* on one of *Dracaena*, for example, having been described by Arens (34).

TAXONOMIC NOTES

The wood anatomy of the species examined suggests that the last word has not yet been said on the delimitation of the genera. For example, ***Phoradendron flavescens*** (Pursh.) Nutt. more closely resembles a *Viscum* (e.g. ***V. album*** L., ***V. capense*** Thunb., and ***V. articulatum*** Burm.) than ***P. crassifolium*** Nutt. and the latter stands out sharply from all the other species examined.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Antidaphne, Arceuthobium,* Atkinsonia, Dendrophthora, Elytranthe, Gaiadendron, Lepidoceras, Loranthus,* Notothixos, Nuytsia, Phoradendron,* Phrygilanthus, Phthirusa, Struthanthus, Tupeia, Viscum.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Elytranthe, (Gaiadendron), (Lepidoceras), Loranthus, (Nuytsia), Phoradendron, (Phrygilanthus), (Phthirusa), (Struthanthus), (Tupeia), Viscum.

LITERATURE

(i) On General Anatomy

Arens **34**, Engler and Krause **646**, Heinricher **942**, **943**, **944**, Koernicke **1264**, McLuckie **1471**, Melchior **1480**, Morini **1554**, Schaeppi **2531**, von Tubeuf **2287**, Wood **2458**.

(ii) On Wood Structure

Burgerstein **310**, Greguss **2522**, Pfeiffer, H. **1712**, Record **1843**, **1851**, **1853**.

239. SANTALACEAE

(FIG. 287 on p. 1192; FIG. 288 on p. 1198)

SUMMARY

(i) GENERAL

This widely distributed family includes trees, shrubs, and herbs which are semi-parasitic on other plants, being in most instances attached to their hosts by means of haustoria which arise from the cortex, endodermis, and pericycle of the parasite. Besides being semi-parasites, some members of the family are strongly xerophytic, and, in correlation with these physiological specializations, the leaves are sometimes reduced or absent, in which case there is frequently assimilatory tissue in the stem, or the stems may even become phylloclades. *Acanthosyris* is noteworthy on account of its axillary thorns, and *Arjona* because of its underground tubers. **Hairs** are infrequent on the dorsiventral or isobilateral leaves, and when present mostly unicellular, although uniseriate, or even tufted forms have been recorded. The **epidermis** is often papillose. **Stomata** are usually rubiaceous, and in some species tend to be transversely orientated on leaves and assimilatory stems. In other species the transverse arrangement is less well defined. In the leaf the **mesophyll** frequently includes groups of silicified cells. Elongated tracheids at the terminations of veins provide another characteristic feature, whilst in a few genera similar elements occur in the mesophyll independently of, but parallel to, the veins. In the young stems **cork** arises superficially; the primary **cortex** often contains stone cells, or, more rarely, sub-epidermal bundles of fibres; the **pericycle** includes isolated strands of fibres interspersed with stone cells in a few species. Sclerenchymatous elements are rare in the secondary **phloem.**

(ii) WOOD

GROUP A

Vessels exclusively solitary, perforations simple, pits to ray cells small and bordered, members very to moderately short. **Parenchyma** diffuse, with numerous chambered crystals, strands of 2–4 cells. **Rays** 2–4 cells wide, with numerous low uniseriates, low, slightly heterogeneous to homogeneous. **Fibres** with numerous distinctly bordered pits, short. Vascular **tracheids** moderately common, together with some cells suggesting vasicentric tracheids.

GROUP B

Vessels in numerous small multiples and typically with a marked oblique or tangential pattern, some genera tending to be ring-porous, sometimes with spiral thickening, perforations simple, intervascular pitting alternate, pits to ray cells often large and simple, members of medium length to moderately short. **Parenchyma** predominantly paratracheal, strands mostly of 2 cells. **Rays** 3–6 cells wide, with very few uniseriates, sometimes high, slightly heterogeneous to homogeneous, usually with prominent solitary crystals. **Fibres** with simple or slightly bordered pits, typically long. Vascular and vasicentric **tracheids** sometimes present.

LEAF

Usually dorsiventral, but species with isobilateral or homogeneous mesophyll also known to occur (see under 'Mesophyll' below). **Hairs** mostly small, unicellular, pointed; uniseriate in species of *Buckleya* and *Pyrularia*; tufted in *Exocarpus latifolius* R. Br. **Cuticle** frequently striated. **Epidermis** composed of cells with straight, or at most slightly sinuous, anticlinal walls; outer walls often strongly thickened. Epidermal cells on the upper surface of the leaf of *Cervantesia tomentosa* Ruiz. et Pav. palisade-like, with thick outer walls and fat bodies in the lumen. Epidermis partly papillose in species of *Arjona*, *Exocarpus*, *Leptomeria*, *Quinchamalium*, *Santalum*, *Thesium*; wholly papillose on the lower surface in *Santalum album* Linn. **Hypoderm** recorded in species of *Henslowia*, *Jodina*, *Santalum*, frequently collenchymatous and sometimes consisting of several layers. **Stomata** occurring on both surfaces or confined to the lower side in different species; usually rubiaceous, but the subsidiary cells sometimes become secondarily divided by walls at right angles to the pore. Some of the stomata in species of *Arjona* and *Quinchamalium* said by Solereder to be surrounded by a relatively large number of unspecialized cells. Ranunculaceous stomata also recorded by Holm (992) in *Comandra*. Stomata tending to be arranged parallel to one another, but transversely to the midrib, in species of *Anthobolus*, *Choretrum*, *Exocarpus*, *Leptomeria*, *Omphacomeria*, *Osyris*, *Santalum*, *Thesium*; the parallel transverse arrangement less well marked in other species of *Osyris*, e.g. in *O. abyssinica* Hochst. and *O. wightiana* Wall. (syn. *O. arborea* Wall., *O. tenuifolia* Engl.), as well as in *Comandra* and *Osyridocarpus*; guard cells parallel to the midrib in *Arjona*; irregularly orientated in species of *Acanthosyris*, *Buckleya*, *Cervantesia*, *Exocarpus*, *Henslowia*, *Jodina*, *Myoschilos*, *Pyrularia*, *Quinchamalium*, *Santalum*.

Mesophyll. Approximately isobilateral structure recorded by Perrot (1695) in young leaves of *Eucarya spicata* Sprague et Summerhayes, but mesophyll becoming wholly converted to palisade tissue when older. Isobilateral structure recorded by Pilger (1724) in *Arjona*, *Jodina*, *Leptomeria*; 1–3 layers of palisade cells towards both surfaces also noted at Kew in *Osyris abyssinica*. Mesophyll, homogeneous and consisting of rounded cells, recorded in species of *Comandra* (Holm 992), *Henslowia*, and *Thesium*; composed wholly of palisade cells in *Osyris alba* Linn. and certain species of *Thesium*; palisade and spongy parenchyma present in other species of *Thesium*; 3 layers of particularly tall palisade cells said to occur in *Cervantesia*. Mesophyll described by Perrot (1695) as dorsiventral in leaves on young stems of *Santalum lanceolatum* R. Br. but as homogeneous in other leaves of the same species. Mesophyll including groups of silicified cells, particularly in the region of the veins, in species of *Acanthosyris*, *Buckleya*, *Comandra*, *Exocarpus*, *Osyris*, *Pyrularia*, *Quinchamalium*, *Santalum*, *Thesium*; walls of these cells either exhibiting silicified protuberances or provided with U-shaped thickenings as seen in transverse sections of the leaf. Conspicuous terminal tracheids nearly always present, although not recorded in species of *Acanthosyris*, *Buckleya*, *Jodina*. Rows of tracheids with bordered pits, or spiral or reticulate thickening, lying parallel to, but independent of, the veins, recorded in species of *Osyris*, *Quinchamalium*, and *Thesium*. Vascular bundles of the **veins** always embedded in the mesophyll; with or without accompanying sclerenchyma according to the species. **Petiole,** in transverse sections through the distal end, exhibiting, in material examined at Kew, a median vascular arc with incurved ends in *O. abyssinica* and a similar vascular arc, but without incurved ends, in *O. wightiana*. Well-developed fibrous elements seen in the 'pericyclic' region of the petiole in both species. Vascular and pericyclic structure of the petiole of *Eucarya spicata* very similar to that of *O. wightiana* according to Perrot (1695); a median vascular strand with incurved ends and entirely surrounded by collenchyma recorded by the same author in the petiole of *Santalum lanceolatum*.

Crystals either solitary or clustered; especially large solitary types present in *Cervantesia* and *Leptomeria*; abundant cluster and sphaerocrystals noted in the mesophyll of *Osyris abyssinica*. Masses of a refractive substance, resembling fat, recorded in the epidermal cells of a few species of *Eucarya* and *Thesium*.

AXIS

YOUNG STEM (Fig. 287 G, I)

Furrowed stems, with hairs in the grooves, recorded by Betts (187) in *Exocarpus bidwilli* Hook. f. **Stomata** transversely arranged in young branches of many members of the family, notably in species of *Anthobolus*, *Choretrum*, *Exocarpus*, *Fusanus*, *Henslowia*, *Jodina*, *Leptomeria*, *Myoschilos*, *Osyris*, *Santalum*, *Thesium*. **Cork** described by Solereder as arising in the epidermis or outermost part of the cortex in all investigated species. A cork-like zone of 6–7 layers of cells, readily stained by iodine green, present below the thickly cuticlarized epidermis of *Eucarya spicata* Sprague et Summerhayes according to Perrot (1695); corresponding tissues in *Santalum lanceolatum* R. Br. described by the same author as much thinner than in the previous species. Phellogen described by Holm (992) as arising on the inside of the pericyclic fibres in *Comandra umbellata* (L.) Nutt.

Primary **cortex** differentiated as assimilatory tissue in species with reduced leaves; sometimes containing stone cells in *Choretrum*, *Henslowia*, *Santalum*, *Thesium*, and occasional sub-epidermal bundles of fibres in *Leptomeria*, *Omphacomeria*, *Santalum*. **Pericycle** usually containing large, conspicuous, isolated strands of fibres, even in herbaceous forms such as *Thesium humifusum* DC. (Fig. 287 G), but the strands of fibres tend to be more or less united to form a ring in certain species, particularly in *Henslowia*. **Phloem** generally in the form of a continuous cylinder apart from the narrow or fan-shaped distal ends of the rays, particularly in woody species; appearing as separate strands on the inside of each of the strands of pericyclic fibres in *Thesium humifusum* (Fig. 287 G) and probably other herbaceous species. Secondary phloem seldom including fibres except in *Omphacomeria* and *Santalum*; stone cells recorded in this tissue in *Henslowia* and *Osyridocarpus*. **Xylem** in the form of a continuous cylinder traversed by narrow rays both in woody species (Fig. 287 I) and in herbaceous forms such as *Thesium humifusum* (Fig. 287 G). Vessels with simple perforations. **Pith** consisting of lignified or unlignified cells or a mixture of both according to the species. **Tanniniferous cells** recorded by Betts (187) in *Exocarpus bidwilli*, and observed at Kew in the cortex and pith of *Osyris abyssinica* Hochst. and *O. wightiana* Wall (syn. *O. arborea* Wall., *O. tenuifolia* Engl.). **Crystals** of the same types as those described under 'Leaf' present also in the axis. Axial columns of large solitary crystals noted at Kew in the phloem of *O. abyssinica,* and somewhat smaller ones in the corresponding position in *O. wightiana*; a few cluster crystals seen in the pith of the same species.

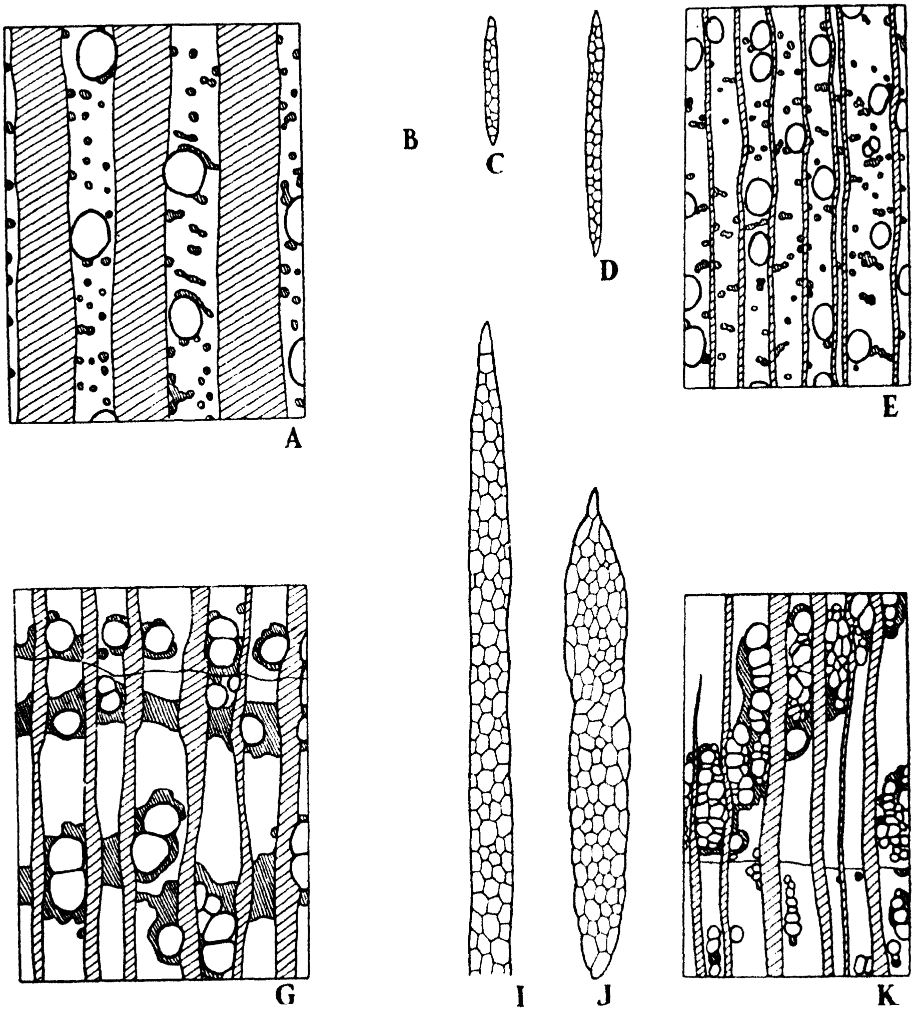


FIG. 288. *SANTALACEAE*

A, *Scleropyrum ridleyi* Gamble. B, *Eucarya acuminata* Sprague et Summerhayes. C, *Exocarpus latifolius* R. Br. D, *Santalum album* Linn. E, *S. album* Linn. F, *Myoschilos oblongus* Ruiz. et Pav. G, *Cervantesia colombiana* A. C. Smith. H, *Jodina rhombifolia* Hook. et Arn. I, *Cervantesia colombiana* A. C. Smith. J, *Acanthosyris falcata* Griseb. K, *Jodina rhombifolia* Hook. et Arn.

PHYLLOCLADES

Phylloclades of species without leaves, or with these members greatly reduced, e.g. *Exocarpus phyllanthoides* Endl. and *E. strictus* R. Br., generally exhibit the same type of structure as an isobilateral leaf, but with the vascular system in the form of a circle of bundles. Vascular strands almost compressed into one plane in some species of *Exocarpus*; composed of a ring of 3 large bundles surrounded by an outer ring of smaller and more numerous vascular strands in *E. strictus*.

WOOD

GROUP A. *Eucarya*, *Exocarpus*, *Osyris*, and *Santalum* (Fig. 288 B–E)

Vessels moderately to very small (mean tangential diameter 25–100 μ); exclusively solitary; 20–95 per sq. mm.; Record (1851) lists *Osyris* as ring-porous. Perforations simple. Intervascular pitting very rare and not observed; pits to ray cells rather rare, small and bordered; striations, due to coalescent apertures among the pits to fibre-tracheids, sometimes present. Solid deposits and tyloses usually present and sometimes moderately abundant. Mean member length 0·2–0·3 mm. **Parenchyma** apotracheal, as cells scattered among the fibres. Chambered crystals, often occupying complete strands, common except in *Osyris*, the chambers with very thick walls; often with dark, gummy contents. Strands of 2–4 cells. **Rays** up to 2–4 cells wide and low; with numerous and low uniseriates (often only 1 or 2 cells high); 8–15 rays per mm.; slightly heterogeneous (Kribs's Type II B) to homogeneous (Kribs's Type I); crystals not observed. **Fibres** with numerous, distinctly bordered pits on both radial and tangential walls. Walls moderately thick to thick. Mean length 0·5–1·0 mm. Vascular **tracheids** moderately common, together with some cells suggesting vasicentric tracheids, being shorter and more densely pitted than the fibre-tracheids.

GROUP B. *Acanthosyris*, *Cervantesia*, *Jodina*, and *Myoschilos* (Fig. 288 G–K)

Vessels moderately to very small (25–100 μ) and extremely small (less than 25 μ) in *Myoschilos oblongus* Ruiz. et Pav.; small multiples of 2–3 cells common; in distinctive radial or oblique groups (dendritic) in *Jodina* (Fig. 288 K) and *Myoschilos*, in tangential lines in *Acanthosyris* and *Cervantesia* (Fig. 288 G), though almost without pattern in some specimens of the latter; very numerous, except in *Cervantesia*; tending to be ring-porous in *Myoschilos* and sometimes, according to Record (1864), in *Jodina*; with spiral thickening in some species of *Acanthosyris* and *Jodina*. Perforations simple. Intervascular pitting alternate, small to medium-sized and sometimes elongated horizontally in *Myoschilos*; pits to ray and wood parenchyma often large, elongated, and simple. Mean member length 0·34–0·38 mm. in *Cervantesia* and *Jodina*, about 0·22 mm. in *Myoschilos*. **Parenchyma** predominantly paratracheal, surrounding the oblique groups of vessels or linking vessels in tangential bands, e.g. in *Cervantesia* (Fig. 288 G); scattered cells (diffuse) present in small numbers in most species and abundant in *Myoschilos oblongus*. Record and Hess (1886) refer to terminal bands in *Acanthosyris*. Strands mostly of 2 cells. **Rays** 3–6 cells wide; considerably more than 1 mm. high in *Cervantesia* and showing evidence of dissection from large to smaller units in *Acanthosyris* and *Jodina*; with very few uniseriates, except in *Myoschilos*; about 13 rays per mm. in *Myoschilos*, but distinctly fewer (6–8 per mm.) in the other genera. Heterogeneous (Kribs's Type II B?) with 1 or 2 marginal rows of square cells, to homogeneous (Kribs's Type I); with occasional sheath cells in *Acanthosyris* and *Jodina*; with numerous solitary crystals except in *Myoschilos*. **Fibres** typically with simple or faintly bordered pits, but with distinctly bordered pits in *Myoschilos*. Walls thick. Mean length 1·6 mm. in

Jodina and 2·3 mm. in *Cervantesia*; much shorter (0·5 mm.) in *Myoschilos*. **Tracheids.** Some cells similar to small vessels, but without perforations, occur commonly in *Jodina* and *Myoschilos*, together with vascular tracheids.

Scleropyrum ridleyi Gamble is intermediate between the 2 groups, being generally similar to Group A (Fig. 288 A), but with rays high and up to 10 cells wide, no crystalliferous parenchyma, and long fibres (1·6 mm.).

PARASITISM AND STRUCTURE OF HAUSTORIA

The mode of parasitism of various members of the family has been described, amongst others, by Hedgcock (930), Herbert (955), Holm (992), Pilger (1724), Rao (1772), Sperlich (2167A), and Woodcock and Zeeuw (2462). It is generally agreed that the parasites become attached to the host plant by various types of haustoria, which penetrate the host tissues partly by mechanical pressure and partly by enzyme action. In most species the haustorium penetrates the host tissues as far as the xylem, the tracheary elements of host and parasite becoming organically connected. The interconnecting vascular elements have frequently been described as phloeotracheids, but, according to Rao, they consist of true vessels in the species of *Choretrum*, *Exocarpus*, *Santalum*, *Scleropyrum*, and *Thesium* which he examined. The haustoria in these genera, according to Rao, differ in structure from those of the Balanophoraceae and semi-parasitic members of the Scrophulariaceae, but recall those of the Olacaceae. In the same genera of Santalaceae the haustoria were found to be simple or compound, the more complex types occurring on hard host roots which are difficult to penetrate. Most haustoria are short-lived, but some of them are capable of secondary growth and may become relatively permanent structures. Rao, like the earlier worker Herbert, concluded that the vascular system in the mature haustorium is normally flask-shaped, but Herbert found this was not true of those haustoria of *Exocarpus sparteus* R. Br. which are sometimes formed independently of the host plant. Herbert also points out that haustoria are lateral organs which do not arise directly from the root tips. He also found that differences in the structure of haustoria are of no generic diagnostic value.

In some members of the family the connexion between host and parasite is less intimate. For example, according to Herbert, there is no direct connexion between the vascular tissues of the host and those of the parasite in *Choretrum laterifolium* R. Br., *Exocarpus sparteus*, and '*Leptomeria spinosa*', organic continuity being maintained only by parenchymatous cells in the cortex. On the other hand, the same author observed direct vascular continuity in *Eucarya acuminata* Sprague et Summerhayes, *E. spicata* Sprague et Summerhayes, and '*Leptomeria preissiana*'. Somewhat superficial penetration by haustoria has been described for *Comandra* by Woodcock and Zeeuw (2462), Hedgcock (930), and Holm (992). The last author concluded that *C. umbellata* (L.) Nutt. is parasitic only when young, becoming partly or wholly autotrophic when more mature. According to Planchon (1730) *Osyris alba* Linn. is so strongly parasitic on grape vines that it causes a serious disease.

Woodcock and Zeeuw (2462) have recorded the occurrence of a clear blue colour, caused by a crystalline deposit associated with the cell walls, in the cortex of the underground stems and roots of '*Comandra palida*'.

TAXONOMIC NOTES

The wood anatomy suggests very strongly that this family is in need of revision.

It has been found convenient, on the basis of wood structure, to separate the genera into 2 groups. Group A, which includes *Santalum*, makes a very satisfactory, uniform group. Group B is not so uniform and there are considerable differences between the genera. *Myoschilos* should perhaps not have been included here; it fits as regards the dendritic pattern of its vessels, in which it resembles *Jodina*, and its parenchyma, but in some other respects it resembles Group A, e.g. fibre and vessel member length, numerous uniseriate rays, absence of crystals in the rays, and distinctly bordered pits in the fibres. *Scleropyrum*, too, is intermediate, but in the opposite manner, the vessels and parenchyma being similar to Group A, but the rays and fibre length similar to Group B.

ECONOMIC USES

The most important product is Indian Sandalwood, obtained from *Santalum album* Linn. Australian Sandalwood is obtained from *Eucarya spicata* Sprague et Summerhayes and *E. acuminata* Sprague et Summerhayes. Sandalwood oils, used in medicine and perfumery, are distilled from the wood of these species, and from various species of *Santalum* (e.g. *S. freycinetianum* Gaud. Hawaiian sandalwood, *S. yasi* Seem. Fiji sandalwood, *S. austro-caledonicum* Vieill. New Caledonian sandalwood), which are of minor importance. *Arjona* is stated to have edible tubers. The fruits of some members of the family are edible, e.g. those of *Acanthosyris*. Cape Sumac (*Colpoon compressum* Berg.) is used in tanning.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Acanthosyris, Anthobolus, Arjona, Buckleya, Cervantesia, Choretrum, Comandra, Eucarya, Exocarpus, Fusanus, Henslowia, Jodina, Leptomeria, Myoschilos, Omphacomeria, Osyridocarpus, Osyris,* Pyrularia, Quinchamalium, Santalum, Scleropyrum, Thesium.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Acanthosyris, Cervantesia, Eucarya, Exocarpus, Jodina, Myoschilos, Osyris, Santalum, Scleropyrum.

LITERATURE

(i) *On General Anatomy*

Benson **173**, Betts **187**, Hedgcock **930**, Herbert **955**, Holm **992**, Perrot **1695**, Pilger **1724**, Planchon **1730**, Rao **1772**, Sperlich **2167A**, Woodcock and Zeeuw **2462**.

(ii) *On Wood Structure*

den Berger and Endert **183**, Betts **188–9**, Brown, F. B. H. **282**, Burgerstein **312**, Chowdhury **409**, Foxworthy **705**, Howard **1088**, Jones **1191**, Kanehira **1206**, **1213**, Maby **1406**, Metcalfe **1497**, Normand **1617**, Pearson and Brown **1679**, Record **1843**, **1851**, **1853**, **1864**, Record and Hess **1886**, Wallis **2348**.

240. GRUBBIACEAE

SUMMARY

A small family of ericoid shrubs with opposite, linear, leathery leaves. The sole genus is *Grubbia* of which a few species occur in South Africa. In the absence of recent published information and of suitable material for examination, the following description is based on that by Solereder, which has also been repeated by Harms (899).

LEAF

Dorsiventral. Surface covered with simple, unicellular **hairs,** the latter sometimes provided with verrucose thickenings. **Stomata** ranunculaceous; confined to the lower surface. Solitary and less frequent clustered **crystals** reported to occur in idioblasts immediately below the epidermis of *G. stricta* A. DC.; clustered crystals also recorded in septate palisade cells in *G. rosmarinifolia* Berg.

AXIS

YOUNG STEM

Hypoderm sharply differentiated from the internal tissues in species belonging to the section *Ophira*, but hypoderm merging imperceptibly into the cortex in species belonging to the section *Strobilocarpus*. **Cork** arising in the epidermis or sub-epidermis; consisting of cells with rather thick walls. **Pericycle** including a composite, continuous ring of sclerenchyma in *G. stricta* A. DC., but only isolated bundles of fibres present in the corresponding position in *G. rosmarinifolia* Berg. **Xylem** characterized by vessels about 30 μ in diameter, provided with simple and bordered pits to the rays, and scalariform perforation plates with 40 or more bars; rays 1–2 cells wide; fibres with bordered pits; parenchyma sparse.

TAXONOMIC NOTES

It will be noted that *Grubbia* differs from the Santalaceae, in which it was included by Bentham and Hooker, in having scalariform perforation plates in the vessels, by the absence of rubiaceous stomata, and of groups of silicified cells or enlarged terminal tracheids from the mesophyll of the leaf. The true affinities of *Grubbia* have not yet been well established. The various views which have been expressed concerning the taxonomic position of the genus have been summarized by Harms (899).

GENUS DESCRIBED

Grubbia.

LITERATURE

On General Anatomy
Harms **899**.

241. MYZODENDRACEAE

(FIG. 289 on p. 1204)

SUMMARY

Undershrubs, all parasitic on trees, and belonging to the single genus *Myzodendron*, which occurs in temperate regions on the Andes. *Myzodendron* is divided into 2 sections: (i) *Eumyzodendron* with leafy continuous branches, and (ii) *Gymnophyton* with leafless, articulated branches. There are corresponding anatomical differences between these 2 sections of the genus. According to Skottsberg (2120), nourishment is absorbed from the host plant by haustoria which are probably homologous with the primary root. In some instances gall-like hypertrophies are formed in the host plant, but at other times the structure is not much modified.

LEAF

Lamina homogeneous; composed of isodiametric cells. **Hairs** simple, unicellular. **Cuticle** strongly developed in *Gymnophyton*. Cells of the **epidermis** said by Solereder to contain crystalline masses in *M. quadrifolium* DC. Skottsberg (2120) refers to a yellow substance in the epidermis of other species as well. **Stomata** present on both surfaces, lying parallel to the midrib. **Mesophyll,** in a number of species, including groups of silicified cells. Conspicuous tracheids, similar to those in the Santalaceae, also present. Vascular bundles of the **veins** embedded in the mesophyll; not accompanied by sclerenchyma.

AXIS

STEM (Fig. 289)

Structure somewhat different in the sections *Eumyzodendron* and *Gymnophyton*. Except where otherwise stated, the following description is largely based on that by Skottsberg (2120).

(i) *Eumyzodendron*

Epidermis becoming replaced by a secondary integumentary tissue perforated by lenticels in *M. brachystachyum* DC. and *M. oblongifolium* DC. Outer part of the **cortex** in the same 2 species including groups of stone cells arranged in a circle in transverse sections; stone cells absent from the corresponding position in *M. quadriflorum* DC. **Vascular system** of *M. brachystachyum* and *M. oblongifolium* (Fig. 289 A–B) appearing, during the first year, as a loose ring of vascular bundles separated by broad, unlignified, medullary rays, the vascular ring being supported externally by mechanical tissue, the latter forming a more completely closed circle in *M. quadriflorum* than in *M. brachystachyum* and *M. oblongifolium*. A second vascular ring, similar to the first, arises in the pith of *M. brachystachyum* and *M. oblongifolium* during the second year. Vascular bundles in the same 2 species never form a closed cylinder, but always remain separated by unlignified medullary rays. One or 2 irregularly orientated, medullary bundles arise during the second year in *M. quadriflorum*. Only a single circle of vascular bundles present in *M. linearifolium* DC. Mechanical tissue in this species consists of a circle of medullary strands and a stronger, horseshoe-shaped strand on the outside of each vascular bundle. **Xylem** stated by Solereder to consist of vessels, with spiral or scalariform thickening and simple perforations, embedded in a ground-tissue of unlignified cells. **Pith** also unlignified. **Crystals** of calcium oxalate frequent in all species; numerous in *M. quadriflorum*.

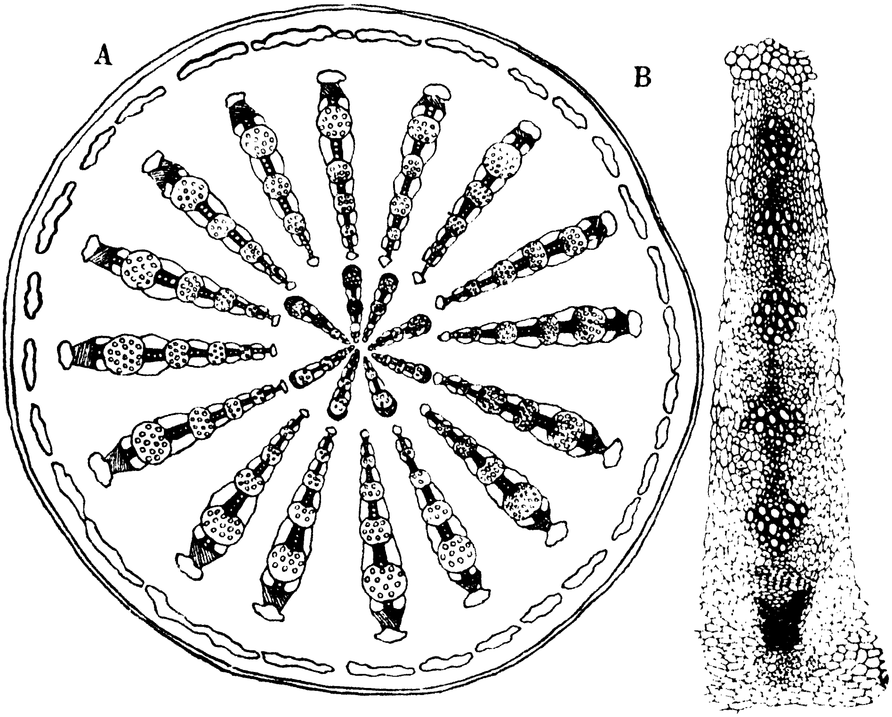


FIG. 289. *MYZODENDRACEAE*
Myzodendron oblongifolium DC.: A, Diagrammatic representation of a transverse section through the axis; B, a single vascular bundle.—By Solereder.

(ii) *Gymnophyton*

Surface covered with curious verrucose prominences, each containing a large air-cavity which communicates with the exterior by an apical stoma. Cells of the **epidermis** covered with thick cuticle; containing spherical particles of a yellowish-brown material of unknown chemical composition, which is insoluble in acids, alkalis, alcohol, and ether. Cells of the outer part of the **cortex** containing similar material to that of the epidermis. A circle of strands of mechanical elements present in the region of the **pericycle. Xylem** forming a continuous cylinder, traversed by narrow primary and occasional secondary rays. Vessels, according to Solereder, all provided with scalariform pitting and simple perforations. **Pith** completely lignified. **Crystals** of calcium oxalate frequent in all species.

TAXONOMIC NOTES

The taxonomic position of *Myzodendron* has been discussed by Skottsberg (2120), who points out that, although the genus resembles the Loranthaceae and Santalaceae in certain respects, it differs from both of these families in others. In Skottsberg's opinion *Myzodendron* resembles *Arjona* and *Quinchamalium* (belonging to the Santalaceae) more strongly than other genera.

GENUS DESCRIBED

Myzodendron.

LITERATURE

On General Anatomy
Skottsberg **2120.**

242. BALANOPHORACEAE

SUMMARY

The Balanophoraceae are a mainly tropical and sub-tropical family of curiously shaped, fleshy herbs, parasitic on the roots of woody plants. They contain little or no chlorophyll, and the vegetative organs are much reduced. The plants consist essentially of tuberous rhizomes, which sometimes bear definite branches from which the peduncles arise, or the inflorescence axis may originate directly from the tuber. Leaves are very much reduced or absent. On the subterranean part of the plant they have been recorded only in *Lophophytum* according to Harms (902). The tuberous, subterranean part of the plant varies considerably in shape, and in size ranges from that of a small nut to that of a human head. Young tubers possess no cotyledons or roots. The anatomical features can best be described under the organs in which they occur.

SCALE LEAVES

Scale leaves consisting of homogeneous tissue; including groups of stone cells in *Langsdorffia hypogaea* Mart. and *Lophophytum mirabile* Schott. et Endl. Most of the leaf cells of *Mystropetalon* said by Harvey-Gibson (914) to have thick, pitted walls. A dense covering of long unicellular **hairs** recorded by the same author on the abaxial surface and margins in *Mystropetalon*. **Stomata** generally absent, but recorded in species of *Cynomorium*. According to Solereder, 3 **vascular bundles** pass into the bases of the scale leaves and there become further divided in *Langsdorffia hypogaea* and *Lophophytum mirabile*; 1 bundle enters the base in *Scybalium fungiforme* Schott. et Endl. and likewise becomes divided at a higher level. One median vascular strand, consisting of short, irregular, reticulate, and spiral tracheids accompanied by a very small-celled phloem, recorded by Harvey-Gibson (914) in *Mystropetalon*. Colour of the leaves in the same genus reddish-brown owing to deposits of an unidentified substance termed 'Mystrin'.

AXIS

RHIZOME AND PEDUNCLES

Hairs infrequent, but unicellular, thin-walled trichomes with swollen bases recorded in *Langsdorffia* and *Thonningia*. Filiform, multicellular hairs also present on the inflorescence of the Helosidoideae, those of *Rhopalocnemis* being glandular. **Epidermis** composed of small cells; devoid of stomata;

including solitary or grouped papillose cells in *Balanophora involucrata* Hook. f. et Thoms. Rhizome of *Mystropetalon* covered externally with an irregular layer of cutinized cells according to Harvey-Gibson (914). Young cells of the ground-tissue provided with specially large **nuclei.** Mature ground-tissue generally yellowish or reddish in colour, and frequently containing reddish-brown cell sap; composed chiefly of large parenchymatous cells, but with somewhat smaller ones towards the periphery of the rhizome and peduncle. Isolated or grouped stone cells present in the ground-tissue in certain species of *Helosis*, *Langsdorffia*, *Lophophytum*, *Rhopalocnemis*, *Scybalium*. **Vascular bundles** always collateral; very much branched and pursuing an irregular course in the tuberous rhizomes and peduncles of *Cynomorium*, *Helosis*, *Langsdorffia*, *Lathrophytum*, *Lophophytum*, *Mystropetalon*, *Rhopalocnemis*, *Sarcophyte*, *Scybalium*. Between 200 and 300 bundles recorded in transverse sections of the rhizome of *Lophophytum mirabile* Schott. et Endl. and *Scybalium fungiforme* Schott. et Endl.; 2 more or less distinct rings of bundles present in the inflorescence axis of *Helosis cayennensis* (Sw.) Spreng. (syn. *H. guyanensis* Rich.); a main ring accompanied by medullary and cortical bundles present in *Langsdorffia hypogaea* Mart. Cylindrical rhizomes of *Helosis* and *Langsdorffia* usually with a single ring of a few isolated vascular bundles, but this arrangement becomes more irregular in the region of local tuberous thickenings. Bundles in the rhizome and inflorescence axis accompanied by a layer of sclerenchyma at the margin of both xylem and phloem in *Helosis cayennensis*. Sieve tubes in the **phloem** of *Helosis* provided with scalariform sieve plates in the terminal and lateral walls. Vessels said by Solereder to have reticulate or striate thickening; perforations simple in *H. cayennensis*. Doubtful scalariform plates also recorded. Tracheids with spiral or reticulate thickening recorded by Harvey-Gibson (914) in the inflorescence axis of *Mystropetalon*; many of the tracheids in the rhizome of the same genus described as scalariform. **Pith** of *Helosis* made up entirely of, or containing numerous, sclerenchymatous fibres.

A waxy or resinous substance known as **balanophorin** is present in the tissues of *Balanophora*, *Langsdorffia*, *Thonningia*. Harms (902) refers to a similar substance in the tuber of *Helosis*. An unidentified chemical substance termed 'Mystrin', possessing quite different properties from balanophorin, abundant in the tissues of the inflorescence axis of *Mystropetalon* according to Harvey-Gibson (914). Starch said by Solereder to occur in the corresponding position in other genera. Solitary and clustered **crystals** recorded in *Balanophora aleutacea* Junghuhn, and sphaerocrystalline masses in *Lophophytum mirabile* Schott. et Endl.

UNION OF HOST AND PARASITE

The Balanophoraceae are attached to their host plants in a very remarkable way. The subterranean, tuberous part of the plant is directly connected with, and sometimes partly surrounds, the nutritional root of the host plant, but there are no haustoria like those in the Loranthaceae, Santalaceae, and related families. At the point of union between host and parasite the cortical tissues of the host root become disorganized, and the xylem splits into strands which penetrate the tissues of the parasite. In some members of the family the host tissue does not invade the parasite to any very great depth, but, in others, penetration is much deeper. Direct connexion between vascular elements of host and parasite are known to occur in some instances. In *Balanophora* and other genera the tissues of both organisms become so intermingled that they cannot readily be distinguished, or a special connecting organ consisting of mixed tissues may be formed. The subject has been well summarized by Harms (902) whose account should be consulted by those needing more detailed information. Strigl's (2212) description of the relation between various species of *Balanophora* and their hosts is also important.

Heinricher (941) has shown how the earlier views of Van Tieghem concerning the vascular structure of *Balanophora* are incorrect. The so-called stele or central cylinder of Van Tieghem consists, according to Heinricher, of vascular branches from the host which have penetrated the ground-tissue of the *Balanophora* tuber. The layers described by Van Tieghem as 'pericycle' and 'endodermis' are really the tissues of the parasite surrounding the vascular elements of the host. Equally incorrect is Van Tieghem's opinion that the large cells in the 'central cylinder' represent a secretory system of *Balanophora.* These cells form part of the ground-tissue of the parasite, through which the branches of the host root grow.

TAXONOMIC NOTES

Some botanists have doubted whether the Balanophoraceae constitute a natural group, and Harms (902) has emphasized that there are considerable differences between some of the genera. They appear to have no close relationship with any other family.

GENERA DESCRIBED

Balanophora, Cynomorium, Helosis, Langsdorffia, Lathrophytum, Lophophytum, Mystropetalon, Rhopalocnemis, Sarcophyte, Scybalium, Thonningia.

LITERATURE

On General Anatomy

Harms **902**, Harvey-Gibson **914**, Heinricher **941**, Mangenot **2527**, Strigl **2212**.

243. EUPHORBIACEAE

(FIG. 290 *a* on p. 1210; FIG. 290 *b* on p. 1211; FIG. 291 on p. 1216; FIG. 292 on p. 1218; FIG. 293 on p. 1220; FIG. 294 on p. 1224; FIG. 295 on p. 1226).

SUMMARY

(i) GENERAL

The most familiar members of this large, widely distributed, but mainly tropical family are the herbaceous and cactus-like Euphorbias. Regarded broadly, however, the family includes plants with many diverse habit forms. Many members are broad-leaved shrubs and trees, whilst species of *Cluytia* and a few other genera are ericoid in habit. *Tragia* and related genera are stem climbers. Some species, especially those from arid regions, have a large root system which may be fleshy and tuberous. Root-thorns have been recorded on the trunks of *Bridelia pubescens* Kurz. The young, hollow stems of *Endospermum* and *Macaranga* are inhabited by ants. The anatomical structure exhibits a wide range of variation in correlation with the diversity of habit, and no important character occurs throughout the numerous tribes into which the family is divided. The leaves include ordinary laminate types with a dorsiventral mesophyll, rolled and furrowed forms which are often centric, whilst, in the succulent species, they are often much reduced. The **hairs** are very diverse and include glandular, non-glandular, and stinging types. **Extra-floral nectaries** are also common. Some of the cells of the **epidermis** may be sclerosed, mucilaginous, silicified, or papillose in different genera and species. No single type of **stoma** is very widespread in the family, and their distribution is also variable. The **cortex** of the **axis** of the cactoid Euphorbias consists largely of palisade assimilatory tissue, which often increases in thickness through the activity of a peripheral meristem. Stone cells are also common in the cortical region. The **pericycle** usually includes a varying amount of sclerenchyma, which may be in the form of a continuous or interrupted ring; less frequently it is absent. The **phloem** often includes isolated or small bundles of fibres, but is seldom stratified into hard and soft portions. The **vascular bundles** are generally collateral. Even in many of the lianes belonging to the family, secondary thickening proceeds normally. On the other hand, **secondary vascular strands** arise in the pericycle of a few genera, whilst **medullary vascular bundles** are known to occur in *Ricinus*. **Intraxylary phloem** occurs in a number of genera. **Crystals** are mostly solitary or clustered, but special types such as sphaerites and styloids also occur. They are sometimes situated in crystal-idioblasts. **Secretory elements** of various kinds are very widespread. Those which secrete latex have the form of tubes, cells, or sacs, but in some instances tanniniferous and other types of material are secreted in similar elements or in intercellular cavities. **Anomalous structure** occurs in a few genera.

(ii) WOOD

I. PHYLLANTHOIDEAE

Group A (*Aporosa Type*)

Vessels often with scalariform perforation plates, intervascular pitting small to minute, pits to ray cells elongated and large, members moderately to very long. **Parenchyma** abundant, diffuse, strands of 8–16 cells. **Rays** of 2 sizes, up to 4–17 cells wide, several millimetres high, markedly heterogeneous, often with more than 10 marginal rows of upright cells. **Fibres** with very thick walls and simple pits, very long.

Group B (*Glochidion Type*)

Vessels with simple perforations, intervascular pitting minute to large, pits to ray cells elongated and large or round and small, members of medium length to moderately long. **Parenchyma** absent or as rare cells about the vessels. **Rays** sometimes of 2 distinct sizes, up to 3–11 cells wide; often up to 2 mm. high, heterogeneous, sometimes markedly so with 10 or more marginal rows of upright cells. **Fibres** septate, with moderately thin to moderately thick walls and simple pits, of medium length to moderately long.

II. CROTONOIDEAE

Vessels with simple perforations, intervascular pitting typically medium-sized to large, pits to ray cells either large and elongated (often scalariform) or similar to the intervascular pitting, members of medium length to moderately short. **Parenchyma** abundant, apotracheal, varying from scattered cells to continuous bands 1–2 cells wide, sometimes with a little paratracheal in addition, strands usually of 8 cells, but only up to 4 in some genera. **Rays** typically 2–3 cells wide or exclusively uniseriate, sometimes 4–5 cells wide, usually more than 1 mm. high, but distinctly lower in several genera, markedly heterogeneous, often with 10 or more marginal rows of upright cells and with more than 1 multiseriate part per ray, sometimes with marked intercellular spaces. **Fibres** with moderately thin to moderately thick walls, pits usually simple, but sometimes with small or distinct borders, of medium length to moderately short. **Latex tubes** sometimes present in the rays.

LEAF

Exhibiting a varied internal structure in correlation with the diversity of external form; dorisventral to centric. Rolled leaves with a furrow on either side of the median vein in species of *Bertya*, *Cluytia*, *Ricinocarpos*. Surface of the leaf frequently covered with **wax**, especially amongst the succulent Euphorbias.

Hairs (Figs. 290 *a*, 290 *b*). Very variable in density and form; including non-glandular, glandular, and stinging types.

A. Non-glandular hairs. (i) Simple, unicellular or uniseriate trichomes (Fig. 290 G) recorded in members of the Phyllantheae, Bridelieae, Crotoneae (always accompanied by more complex types in this tribe), Acalypheae, Dalechampieae, Hippomaneae. (ii) Two-armed hairs recorded in *Argithamnia*, *Chiropetalum*, *Ditaxis*, *Pausandra*, and *Tetrorchidium*. (iii) Multicellular branched hairs in species of *Mabea* and *Phyllanthus*. (iv) Tufted, stellate and peltate hairs (Fig. 290 E, F, H, L, R, S), with transitional forms between these types, widely distributed, e.g. according to Léandri (1327) in *Croton*. (v) Simple, shaggy hairs present in the Acalypheae and Phyllantheae. (vi) Candelabra hairs (Fig. 290 K) with a multicellular axis in *Croton*.

B. Glandular hairs. Widely distributed, but stalked glands said by Pax and Hoffmann (1673) to be absent from the Hippomaneae. (i) With short stalks and unicellular heads in species of *Bertya* and *Beyeria*. Club-shaped glands situated in furrows in the leaf also occur in *Bertya*. (ii) Glandular shaggy hairs with long stalks in *Caperonia*. (iii) Stalked, multicellular glands in *Acalypha*, *Cephalocroton*, *Tragia*. (iv) Vesicular scales in pits in the epidermis in *Hymenocardia*. (v) Spherical glands sunk in the surface of the leaf in *Acidocroton*, *Coccoceras*, *Coelodiscus*, *Macaranga*, *Mallotus*. (vi) Sessile, disk-shaped glands appearing as white, yellow, red, or brown spots on the under surface of the leaf, recorded by Pax and Hoffmann (1673) in many species of *Acalypha*, *Coccoceras*, *Hymenocardia*, *Macaranga*, *Mallotus*, *Trewia*.

C. Stinging hairs. Stinging hairs, similar to those in Fig. 290 P and Q, and sometimes containing crystals, recorded by Pax and Hoffmann (1673) in *Cnidoscolus* and in the Dalechampieae and Plukenetiinae. Large, conspicuous, **extra-floral nectaries** of the types in Fig. 290 M, N, and O sometimes present. These occur at the bases of the petioles, replacing or associated with the stipules, or, less frequently, at the base of, or at a higher level on, the lamina. Glands of this type rare on the upper surface of the lamina, although sometimes occurring on the leaf teeth. These glands recorded particularly in

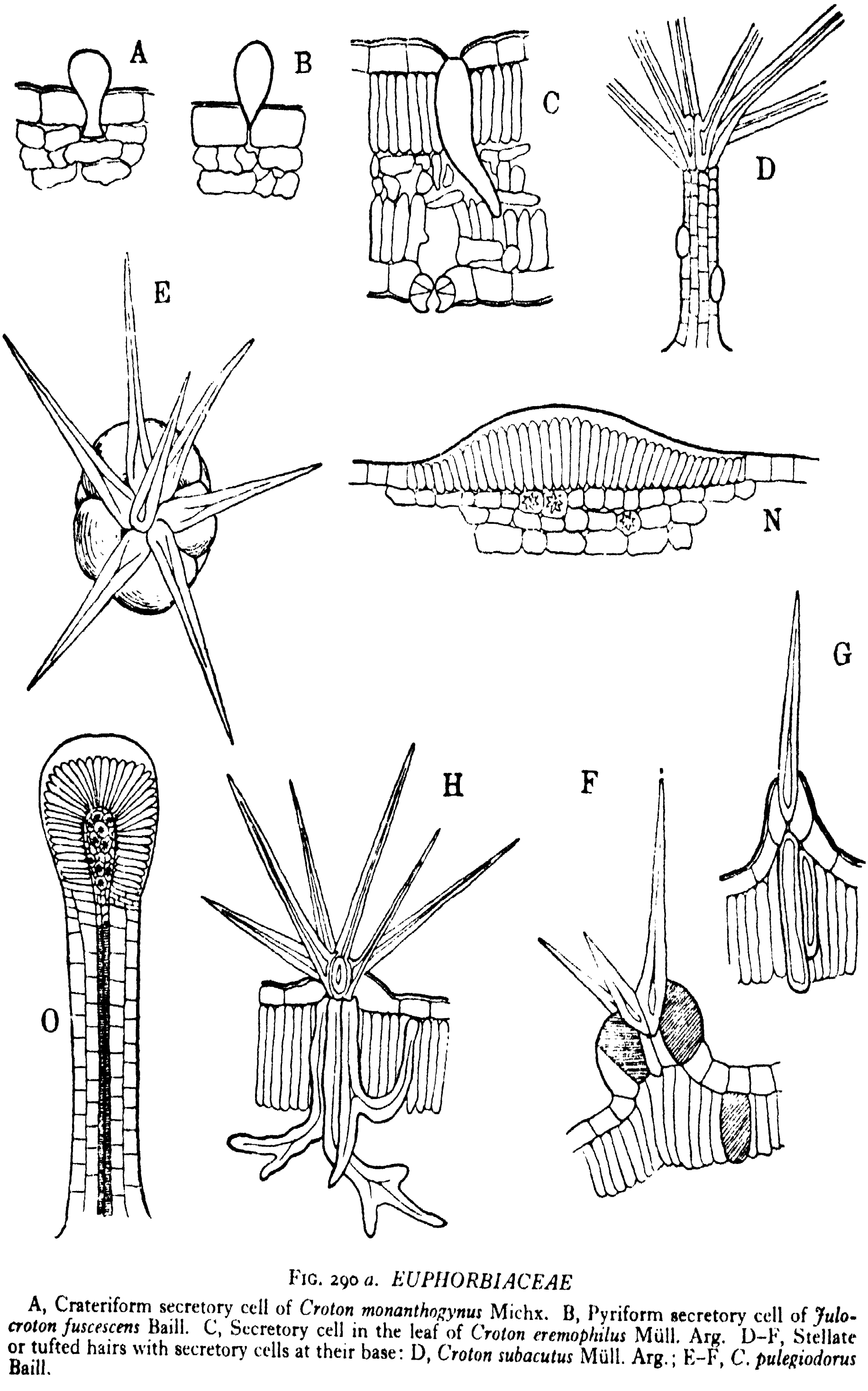


FIG. 290 *a*. *EUPHORBIACEAE*

A, Crateriform secretory cell of *Croton monanthogynus* Michx. B, Pyriform secretory cell of *Julocroton fuscescens* Baill. C, Secretory cell in the leaf of *Croton eremophilus* Müll. Arg. D–F, Stellate or tufted hairs with secretory cells at their base: D, *Croton subacutus* Müll. Arg.; E–F, *C. pulegiodorus* Baill.

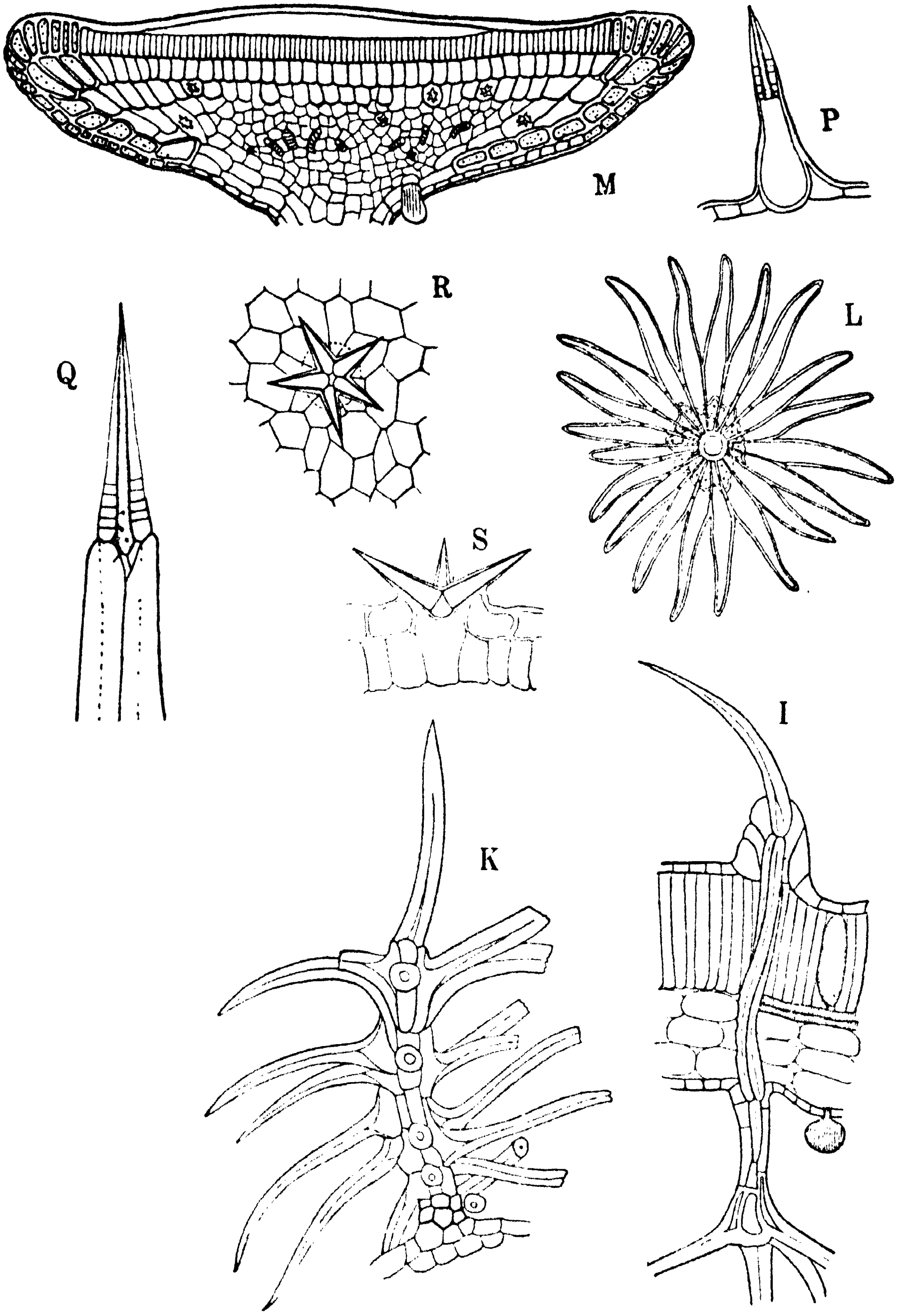


Fig. 290 *b*. *EUPHORBIACEAE*

G–L, Various trichomes: G, *C. exuberans* Müll. Arg.; H, *C. agoensis* Baill; I, *Julocroton fuscescens* Baill.; K, *Croton discolor* Willd.; L, *C. floribundus* Spreng. M, Patelliform gland of *C. glandulosus* Linn., section. N, Glandular margin of the leaf of *C. refractus* Müll. Arg. in section. O, Morulose gland of *C. ciliato-glandulosus* Orteg. P–Q, Stinging hairs of *Tragia cissoides* Müll. Arg. R–S, Hairs containing clustered crystals, from *Plukenetia*.—A–D, G–H, and M–O after Frömbling, E–F, I–K, and P–Q by Solereder, L after Bachmann, R–S after Rittershausen.

Croton, *Excoecaria*, *Hevea* (Keuchenius 1235), *Macaranga*, *Micrandra*, *Ricinus*. For mode of development of extra-floral nectaries in *Ricinus* see Reed's (1895) article.

Epidermis consisting of cells with straight or sinuous anticlinal walls; the outer walls of varying thickness; inner walls strongly thickened in species of *Actinostemon*, *Croton*, *Givotia*, *Senefeldera*. Lower epidermis very strongly sclerosed in species of *Amanoa* and *Discocarpus*; composed of small cells with heavily cutinized papillae in *Glochidion littorale* Blume (Kienholz 1236). Santos (1993) reports cuticular striations radiating from the 2 sides of the stomata on the lower epidermis of *Excoecaria agallocha* Linn. Marginal pits to the epidermal cells occur in species of *Aporosa*, *Bischoffia*, *Drypetes*, *Hemicyclia*. Mucilaginous epidermal cells recorded in certain species of *Acalypha*, *Actephila*, *Andrachne*, *Antidesma*, *Aporosa*, *Baccaurea*, *Bridelia*, *Claoxylon*, *Hieronyma*, *Homonoia*, *Hymenocardia*, *Pera*, *Petalostigma*, *Phyllanthus*, *Richeria*, *Securinega*, *Tragia*. Groups of silicified epidermal cells present in species of *Actinospermum*, *Bernardia* (immediately around the trichomes), *Manihot*, *Pausandra*, *Sebastiania*, *Trigonostemon*. Lower epidermis sometimes papillose in species of *Alchornea*, *Amanoa*, *Breynia*, *Cluytia*, *Conceveiba*, *Croton*, *Euphorbia*, *Glochidion* (papillae cutinized in *G. littorale* Blume (Kienholz 1236)), *Hevea*, *Homonoia*, *Mabea*, *Macaranga* (numerous species), *Mallotus*, *Manihot*, *Maprounea*, *Phyllanthus*, *Securinega*, *Stillingia*. Upper epidermis papillose in a few species of *Euphorbia*, *Macaranga*, *Mallotus*, *Ricinus*. **Hypoderm,** usually a single layer, recorded in species of *Agrostistachys*, *Aleurites*, *Bischoffia*, *Drypetes*, *Euphorbia* (composed of specially large cells on the lower side), *Excoecaria*, *Gelonium*, *Glochidion* (Kienholz 1236), *Hymenocardia* (locally), *Pachystroma*, *Phyllanthus* (sometimes local). A hypoderm of many layers of cells present beneath the upper epidermis in species of *Micrantheum* and *Stachystemon* with ericoid leaves.

Stomata, except in the Crotoneae, usually confined to the lower surface; occurring more rarely on both surfaces, e.g. according to Holm (994, 1051) in *Euphorbia corollata* Linn. and *Stillingia sylvatica* Garden. Stomata also recorded on both surfaces of the isobilateral leaves of *Euphorbia radians* Benth. by Reiche (1910). Stomata usually rubiaceous, e.g. in the Acalypheae, Dalechampieae, Euphorbieae (in *Euphorbia* and *Mercurialis*), *Excoecaria* (Santos 1993), *Glochidion* (Kienholz 1236), Hippomaneae (except sometimes in *Manihot*), Phyllantheae (except some of the Euphyllantheae), *Stillingia* (Holm 1051); generally cruciferous in *Andrachne*, *Aporosa*, *Baccaurea*, *Richeria*. Dommel (596) found the stomata of succulent species of *Euphorbia* from Madagascar to be mostly rubiaceous and lying parallel to the axis (stem), a few ranunculaceous types being present amongst them. Stomata in European species of *Euphorbia*, on the other hand, predominantly ranunculaceous, less sunken, and with the guard cells less cutinized than in the tropical species. Mixed cruciferous and rubiaceous stomata also occur, sometimes in a single leaf, in the Euphyllantheae. Stomata exceptionally small in species of *Euphorbia* belonging to the section *Anisophyllum*.

Mesophyll. A layer of palisade cells below the upper epidermis, and 'festoon' palisade around the bundles, recorded in '*Euphorbia polygonifolia*' by Starr (2188). Mesophyll in the numerous species of *Croton* examined by Léandri (1327) including 1–2 layers of palisade and a narrow region of spongy tissue. The cells of the lowest layer of spongy tissue strongly thickened on the side towards the interior of the leaf in *Microdesmis casearifolia* Planch. Sclerenchymatous elements in the mesophyll recorded in species of *Acalypha*, *Alchornea*, *Bernardia*, *Chondrostylis*, *Conceveiba*, *Dalechampia*, *Pera*, *Phyllanthus*. Similar elements, but with stratified walls, also known to occur in *Actephila*, *Actinostemon*, *Chaetocarpus*, *Erismanthus*, *Pausandra*, *Sebastiania*, *Trigonostemon*. Tubular tracheids with delicate spiral thickening present in the spongy mesophyll of *Pogonophora schomburgkiana* Miers. Enlarged terminal tracheids recorded in species of *Amanoa*, *Euphorbia*, *Givotia*, *Mabea*, *Sebastiania*, *Stillingia*.

Vascular bundles of the **veins** accompanied by sclerenchyma in some species but not in others. Sclerenchyma said to be absent from around the veins in the Euphorbias. The smaller veins sometimes vertically transcurrent in *Alchornea*, *Amanoa*, *Aporosa*, *Bernardia*, *Conceveiba*, *Croton*, *Discocarpus*, *Hevea*, *Hippomane*, *Hymenocardia*, *Macaranga*, *Mallotus*, *Manihot*, *Richeria*, *Savia*, *Securinega*, *Stillingia*, *Trewia*. Vascular bundles surrounded by a sheath of large parenchymatous cells in a few species of *Euphorbia*, especially in the section *Anisophyllum*. Similar cells containing tannin situated around the sclerenchyma of the veins in species of *Amanoa*, *Discocarpus*, *Pseudolachnostylis*.

Vascular bundles of the veins generally, but not invariably, including intraxylary phloem in *Croton* according to Léandri (1327).

Petiole (Fig. 291 A, C, E, G, I) examined in 125 genera by Dehay (557), according to whom 3 leaf-traces enter the base in most species, although higher numbers (up to 8 in *Ricinus*) were observed in a few instances. According to Dehay, in this family transverse sections taken at any level in the petiole are generally alike. Dehay observed 4 main types of petiolar vascular structure in transverse sections, with variations of each type, in different genera and species. (i) A closed vascular cylinder, consisting of an abaxial, semi-circular strand of xylem and phloem and of an adaxial plate of xylem and phloem closing the gap between the ends of the abaxial arc. This type of vascular structure, regarded as basic for the family, is more or less dissected in some of the genera and species. It occurs in typical form in *Croton tiglium* Linn., but is widely distributed in many of the genera and in all of the tribes. (ii) A continuous or dissected cylinder, not consisting of 2 distinct parts as in (i). This occurs in typical form in *Manihot glaziovii* Müll. Arg., and also in many other members of the family. (iii) An open arc of vascular bundles enclosing 1 to several medullary strands, e.g. in *Hieronyma oblonga* (Tulasne) Müll. Arg. Similar, but with a concentric medullary vascular system in *Cordemoya integrifolia* (Willd.) Baill. (iv) An open vascular arc with the ends very much incurved, e.g. in *Bridelia minutiflora* Hook. f. Continuous or dissected vascular arcs occur chiefly in the Glochidiinae and Phyllanthinae. Additional vascular strands frequent in the wings in all of the above types. For further particulars, Dehay's very detailed article should be consulted.

Less extensive observations made at Kew on the petiolar vascular structure tend to confirm Dehay's conclusions. Transverse sections through the distal ends of petioles examined at Kew exhibit a solitary, shallow, crescentic vascular strand in *Andrachne colchica* Fisch. et Mey. (Fig. 291 C) and *Securinega flueggioides* Müll. Arg.; a shallow arc of a few, widely spaced, collateral vascular bundles in *Mercurialis perennis* Linn. (Fig. 291 A) and *Pedilanthus tithymaloides* (L.) Poit.; a deep crescent of widely spaced, collateral bundles in *Acalypha* sp. (Fig. 291 E); a circle of 1 large adaxial and 3 smaller abaxial, widely spaced, bicollateral bundles, connected by a continuous cylinder of phloem in *Croton eleuteria* (L.) Benn. (Fig. 291 G); vascular cylinder more continuous in *Drypetes arguta* Hutchinson and *Hevea brasiliensis* (H. B. et. K.) Müll. Arg.; a cylinder of about 12 bundles in *Ricinus communis* Linn. (Fig. 291 I). Petiole, in the numerous species of *Croton* examined by Léandri (1327), generally supplied by a large cylinder of xylem and phloem, but in some species, with an arc of 3 distinct bundles accompanied by fibres.

Crystals secreted in solitary and clustered forms, both types sometimes occurring together in a single plant. Special forms of crystals include: (A) Sphaerites in the mesophyll of *Croton*, *Crotonopsis*, *Eremocarpus*; similar bodies in hemispherical, projecting, epidermal cells in both leaf and axis of *Acalypha* and *Claoxylon* as well as in the pith of *Gelonium*. (B) Crystals shaped like a V or W recorded in the mesophyll of some species of *Phyllanthus*. (C) Styloids present in the phloem of both leaf and stem of *Bernardia*, *Claoxylon* (mesophyll), *Erythrococca* (mesophyll), *Pachystroma*, *Phyllanthus*; similar but less typical bodies present in *Colliguaja* and *Excoecaria* as well as in the terminal cells of the stinging hairs of *Cnesmone*, *Dalechampia*, *Tragia*. According to Pax and Hoffmann (1673) the roughness of the leaf of *Claoxylon* and its allies is due to the large size of the crystalliferous cells. (D) Large or small crystal idioblasts fairly common. (i) Containing clustered crystals. Relatively small ones recorded in both the upper and lower epidermis in species of *Agrostistachys*, *Aleurites*, *Amperea*, *Bridelia*, *Cleidion*, *Coelodiscus*, *Conceveiba* (pro parte), *Crotonogyne*, *Hippomane*, *Homonoya*, *Jatropha*, *Julocroton*, *Manihot*, *Manniophyton*, *Ostodes*, *Pausandra*, *Securinega*, *Trewia*; larger ones penetrating into the mesophyll in *Acalypha* (pro parte), *Acidocroton*, *Alchornea*, *Claoxylon*, *Dalechampia*, *Givotia*, *Jatropha* (pro parte), *Mallotus*; roundish idioblasts arranged in small groups in *Caperonia*. (ii) Containing solitary crystals. Small ones recorded in the epidermis only in a few species of *Cnesmone* and *Dalechampia*, and larger ones extending into the mesophyll in *Erismanthus*, *Microdesmis*, *Pogonophora*, *Stillingia* (pro parte). (iii) Large crystal idioblasts, sometimes appearing as transparent dots in the leaf, also occur in more deeply seated positions in the mesophyll, especially in the Crotoneae, but also in other sections of the family. (iv) Small clustered crystals in chambered cells of the palisade tissue recorded in species of *Alchornea*, *Cephalocroton*, *Hevea*. (E) Crystalloids in the mesophyll, around the veins of the leaf, and also in the primary cortex of the axis recorded in *Euphorbia splendens* Bojer. Similar bodies also recorded in the latex of *Jatropha*. (F) Crystals shaped like a whetstone, and variously described as consisting of calcium oxalate or abietenic acid recorded by Solereder in the cortex of *Euphorbia splendens* (G) Sphaerites, variously described as consisting of calcium phosphate, calcium malophosphate, or calcium malate, recorded by Solereder in specimens of the cactoid and other Euphorbias, as well as in *Pedilanthus*, when preserved in alcohol.

For details concerning the distribution and morphology of the calcium oxalate crystals in *Ricinus communis* Linn. see Scott's (2071) article.

Secretory elements. The following types of secretory elements recorded in the family. (A) Laticiferous cells. (B) Laticiferous vessels. (C) Rows of laticiferous sacs. (D) Tannin sacs and rows of tannin cells. (E) Elongated sacs with wide lumina and usually brown contents. (F) Secretory cells with resinous contents. (G) Secretory lacunae. (H) Mucilage lacunae.

A. Laticiferous cells, not always clearly distinguished from laticiferous vessels in the literature, are said to be present in the Acalypheae, Crotoneae, Euphorbieae, Hippomaneae, especially in species of *Actinostemon*, *Adenocline*, *Adenopeltis*, *Aleurites*, *Anthostema*, *Cluytia*, *Codiaeum*, *Colliguaya*, *Croton*, *Euphorbia*, *Excoecaria*, *Hippomane*, *Hura*, *Jatropha*, *Joannesia*, *Mabea*, *Macaranga*, *Maprounea*, *Mercurialis*, *Omphalea*, *Ostodes*, *Pachystroma*, *Pedilanthus*, *Ricinus*, *Sebastiania*, *Senefeldera*, *Stillingia*, *Synadenium*, *Trigonostemon*. Laticiferous cells are laid down in the seedling in the region of the cotyledonary node. In mature plants they occur in the pith and primary cortex of the axis as well as in the veins and sometimes free in the mesophyll of the leaf. Contents generally milky in living material, but becoming brown or grey in herbarium specimens. Latex sometimes containing clustered crystals in *Hura* and *Mabea*; tetragonal, flake-like crystalloids in *Jatropha*; rod- or bone-shaped starch grains in species of *Euphorbia*, *Hippomane*, *Hura*, *Pedilanthus*.

B. Segmented or unsegmented laticiferous vessels present in a few genera. Unsegmented vessels recorded in *Hevea*, *Jatropha*, *Manihot*, and *Pachystroma*, as well as in the tribes Euphorbieae and Hippomaneae. Laticiferous canals noted at Kew in species of *Acalypha*, *Codiaeum*, *Croton*, *Euphorbia*, *Hevea*, and *Pedilanthus*. Laticiferous vessels occur chiefly in the phloem of both stem and leaf, at the margin of the pith and in the primary cortex. They sometimes extend into the mesophyll. Abundant laticiferous canals recorded by Léandri (1327) in the cortex and phloem of numerous species of *Croton* from Madagascar, and in all parts of the bark of *Excoecaria agallocha* Linn. by Santos (1993). According to Cummings (513) the latex system in *Euphorbia* originates as a few specialized cells in the cotyledonary node which subsequently develop into branching coenocytes. The development of the laticiferous system has also been examined in *Euphorbia marginata* Linn. by Cameron (330), who found that the portion of the system in the cortex of the hypocotyl, from which branches extend into the cotyledons, is largely independent of the laticiferous elements of the stem.

C. Rows of laticiferous sacs. Recorded only in *Micrandra*. Component cells provided with rather wide lumina; exhibiting varying degrees of elongation; filled with grey, granular material in herbarium specimens; occurring in the pith, phloem, and primary cortex of the axis, or lying independently of the veins in the mesophyll. No other types of secretory organ recorded in *Micrandra*.

D. Tanniniferous cells, filled with brown contents in herbarium material, very widely distributed; occurring either singly or united in groups.

E. Elongated sacs with brown contents. These are often very long and easily confused with laticiferous cells, but usually differ from the latter in being confined to the pith and in having a larger diameter (up to 95 μ); occasionally surrounded by small cells resembling an epithelium. Occurring especially in the pith and sometimes also in the phloem, pericycle, and primary cortex; recorded only in species of *Alchornea*, *Amanoa*, *Givotia*, *Mallotus*, *Pausandra*, *Pogonophora*, *Uapaca*.

F. Secretory cells with oily or resinous contents, sometimes appearing as transparent dots in the leaf, recorded in species of *Andrachne*, *Bischoffia*, *Croton*, *Crotonopsis*, *Eremocarpus*, *Julocroton*, *Mareya*, *Phyllanthus*, *Ricinus*. Secretory cells of *Ricinus communis* present in the epidermis on both sides of the leaf, but extending somewhat into the mesophyll; contents bright and highly refractive in living material, but yellowish-brown when dried. Contents of the secretory cells of the Eucrotoneae bright yellow, translucent; often emitting a pleasant aromatic scent even in dried material. Secretory cells in the Eucrotoneae occurring in the epidermis, primary cortex, phloem, and pith of the axis and in the epidermis and mesophyll of the leaf. Secretory cells of the leaf raised above the surface or embedded in the mesophyll in different instances (Fig. 290 A–C), several types sometimes occurring side by side in a single plant.

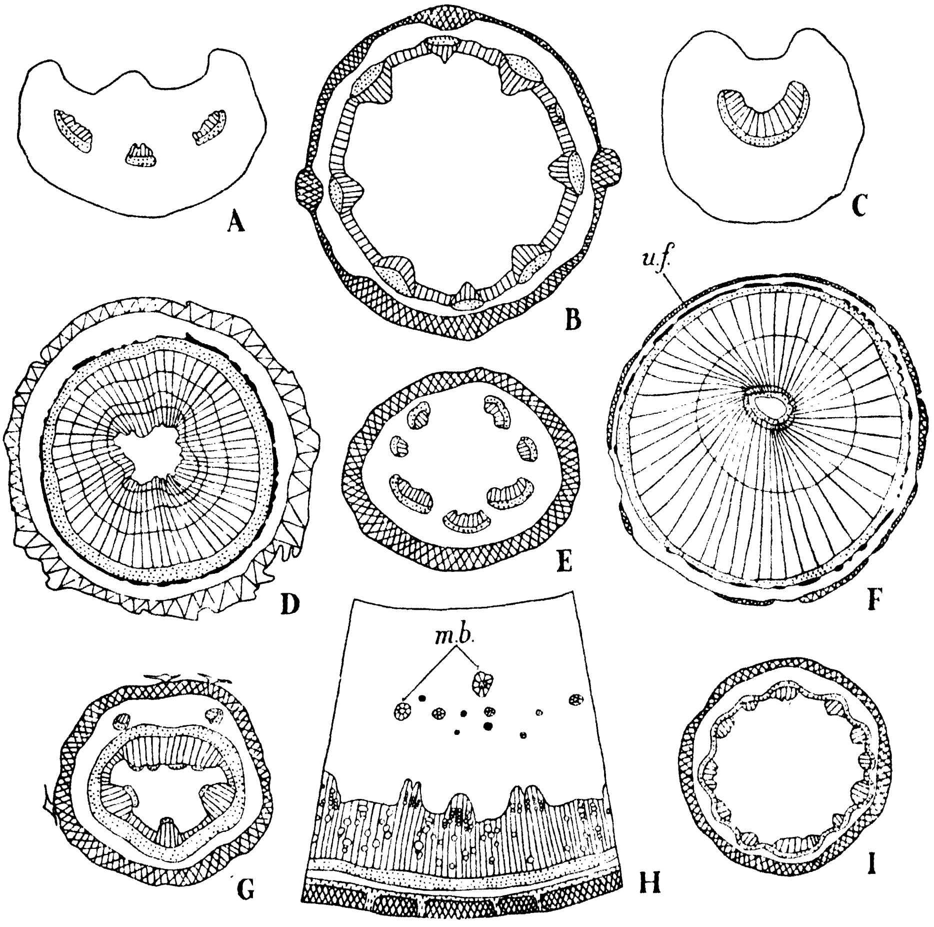


Fig. 291. *EUPHORBIACEAE*

A, *Mercurialis perennis* Linn. Petiole ×14. B, *M. perennis* Linn. Stem ×19. C, *Andrachne colchica* Fisch. et Mey. Petiole ×42. D, *Drypetes arguta* Hutchinson. Stem ×17. E, '*Acalypha wilkesiana* Müll. Arg.' Petiole ×11. F, *Croton eleuteria* Benn. Stem ×6. G, *C. eleuteria* Benn. Petiole ×33. H, *Ricinus communis* Linn. Stem ×7. I, *R. communis* Linn. Petiole ×5.

m.b. Medullary bundles. *u.f.* Unlignified fibres.

G. Secretory cavities, filled with colourless, yellow, or brown material and surrounded by secretory cells, present in nearly all species of *Cluytia* (mesophyll and cortex), *Gelonium* (mesophyll), *Hura* (sub-epidermis). Secretory cavities in *Cluytia* appearing as transparent dots in the leaf; those of *Gelonium* occupying inflated, transparent areas in the leaf according to Pax and Hoffmann (1673).

H. Mucilage cavities. Groups of cells with mucilaginous walls break down to form cavities in the primary cortex of the axis of species of *Adriana*, *Antidesma*, *Baccaurea*, *Bischoffia*, *Hieronyma*, *Hymenocardia*, *Securinega*.

AXIS

STEM (Fig. 291 B, D, F, H)

Cork originating in the epidermis in species of *Acalypha*; sub-epidermal in species of *Andrachne*, *Codiaeum*, *Croton* (Fig. 291 F), *Drypetes* (Fig. 291 D), *Euphorbia*, *Pedilanthus*, and *Phyllanthus*; arising in the outer part of the cortex in a large number of genera in all sections of the family, and in the inner part of the cortex in species of *Amperea*, *Andrachne*, *Baccaurea*. Pericyclic cork occasional. Cork cells exhibiting a very varied structure. Outer cells suberized and inner cells unsuberized in *Excoecaria agallocha* Linn. according to Santos (1993). Walls of the cork cells often encrusted with small crystals in *Croton*. Cork sometimes replaced by a persistent, thick-walled epidermis, e.g. in *Euphorbia corollata* Linn. according to Holm (994). Lacunar, palisade, assimilatory tissue present in the **cortex** of the succulent Euphorbias; the surface of the stem above these regions is perforated by stomata. The cortical tissue of the cactoid Euphorbias is said to increase in thickness by means of a peripheral meristematic zone. Outer part of the primary cortex frequently collenchymatous and containing stone cells, the latter being especially abundant in *Aporosa* and *Hemicyclia*. A ring of stone cells embedded in phelloderm recorded in *Joannesia*, and in the innermost part of the primary cortex in *Pogonophora*. Fibrous cells also present in the cortex and pith of *Conceveiba* and *Euphorbia*. Intercellular spaces in the cortical collenchyma of *Pera* filled with highly refractive material. **Endodermis** usually not well defined, but occurring as an amyliferous layer, e.g. in *Euphorbia radians* Benth. according to Reiche (1910). **Pericycle** sometimes containing isolated strands of fibres, e.g. in *Actephila* (pro parte), *Aporosa* (pro parte), *Croton* (surrounded by crystalliferous cells) (Léandri 1327), *Discocarpus*, *Euphorbia*, *Excoecaria* (Santos 1993), *Hieronyma* (pro parte), *Hymenocardia*, *Stillingia*, but fibres frequently united to form a ring in very young material. A composite, continuous ring of sclerenchyma developed, e.g. in *Actinostemon* (pro parte), *Alchornea* (pro parte), *Amanoa*, *Aporosa* (pro parte), *Chaetocarpus* (pro parte), *Cheidion*, *Cluytia* (slightly interrupted), *Conceveiba*, *Drypetes*, *Gelonium*, *Hevea*, *Hieronyma* (pro parte), *Homonoia*, *Macaranga* (pro parte), *Maprounea*, *Microdesmis*, *Pera*, *Savia*, *Sebastiania*, *Senefeldera*, *Symphyllia*. White or yellow walls of the pericyclic fibres often conspicuously stratified. Pericyclic sclerenchyma poorly developed in, or absent from, the Stenolobeae according to Pax and Hoffmann (1673), and none seen in species of *Codiaeum* and *Mercurialis* examined at Kew. **Phloem** rarely stratified into zones of hard and soft tissue, although this feature has been recorded in *Bridelia stipularis* (L.) Blume. Small strands of, or isolated, phloem fibres fairly common.

Walls of the phloem fibres conspicuously stratified. Parenchyma between the phloem fibres, sclerosed in *Securinega acidothamnus* Müll. Arg. **Xylem** (Fig. 291 B, D, F, H) in the form of a continuous cylinder traversed by narrow rays in all of the genera examined at Kew. A continuous cylinder of xylem

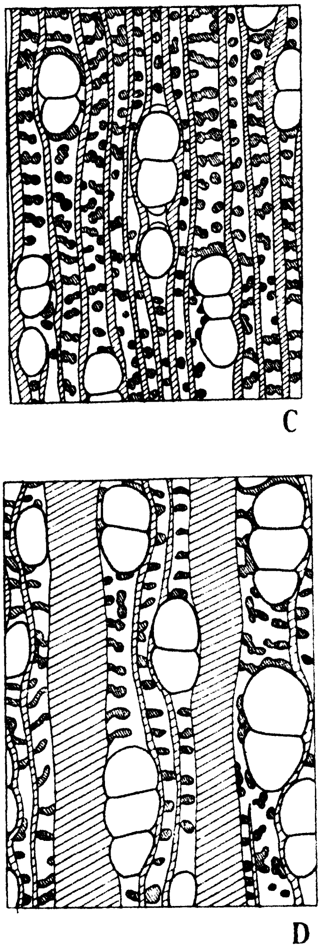


FIG. 292. *EUPHORBIACEAE—PHYLLANTHOIDEAE*. Group A
A, *Richeria grandis* Vahl. B, *Aporosa lunata* Kurz. C, *Drypetes brownii* Standley. D, *Baccaurea motleyana* Müll. Arg. E, *Putranjiva roxburghiana* Wall. F, *Drypetes brownii* Standley.

traversed by uniseriate rays recorded by Léandri (1327) in numerous species of *Croton* from Madagascar. Xylem much reduced and dissected into distinct bundles separated by broad parenchymatous rays in succulent species of *Euphorbia*. Vessels provided with simple perforations and/or scalariform plates; scalariform perforation plates noted at Kew in young stems of *Drypetes* and *Mercurialis*; scalariform lateral pitting also seen in *Drypetes*. For **intra-** and **interxylary phloem** see under 'Anomalous Structure', p. 1228. Secondary thickening frequently normal in **lianes** belonging to the genera *Bridelia*, *Croton*, *Dalechampia*, *Omphalea*, *Phyllanthus*, *Tragia*, but see also under

'Anomalous Structure', p. 1228. Numerous **cortical vascular bundles** present in succulent species of *Euphorbia* (Trumke 2286). For **medullary bundles** see under 'Anomalous Structure'. **Pith** lignified or unlignified, frequently containing stone cells; consisting of large parenchymatous cells, some of the central ones being sclerosed, in *Croton* (Léandri 1327). Transverse walls of the pith cells of *Cluytia alaternoides* Linn. provided with large circular or elliptical perforations. **Crystals** and **secretory elements,** see under 'Leaf' on p. 1214. **Developmental anatomy.** The differentiation and course of the vascular bundles in the node of *Ricinus communis* Linn. has been described by Reynolds (1930 and 1931). The mode of development of the vascular anatomy in the same species has also been described by Sarkany (1996).

WOOD

I. PHYLLANTHOIDEAE

(*a*) *Group A. Aporosa Type* (Fig. 292)

Antidesminae p.p.: *Aporosa*, *Baccaurea*, *Dicoelia*, *Maesobotrya*, *Protomegabaria*, *Richeria*.

Vessels very variable in size even within genera, 50–210 μ mean tangential diameter, mostly 70–125 μ; typically with numerous multiples of 2 or 3 cells and often of 4 or more cells; mostly 10–20 per sq. mm., but more numerous (20–40) in *Dicoelia* and *Maesobotrya*. Fine spiral thickening in the vessel ends observed by Janssonius (1154) in *Aporosa* and *Baccaurea*. Perforation plates scalariform, simple, or both. Scalariform plates observed in *Aporosa*, *Baccaurea*, *Drypetes*, *Protomegabaria*, *Putranjiva*, *Richeria* (to ray cells only), and *Securinega*, and reported by Solereder in *Actephila*, *Hieronyma*, and *Richeria*, by Heimsch (938) in *Dicoelia*, and by Milanez (1520) in *Paradrypetes*. Intervascular pitting opposite in *Protomegabaria stapfiana* Hutch., alternate and small to minute in the other genera; pits to parenchyma large, elongated, and simple, except in *Dicoelia*. Typically without contents. Mean member length 0·9–1·6 mm. **Parenchyma** abundant, as scattered cells and numerous, short, uniseriate bands. Commonly with chambered crystals. Strands of 8 or more cells, sometimes up to 16. **Rays** of 2 distinct sizes, the larger typically 4–17 cells wide, but seldom more than triseriate in *Dicoelia*; commonly several millimetres high, but sometimes dissected into smaller units; uniseriate rays typically high and numerous and composed of high upright cells; 8–15 rays per mm.; markedly heterogeneous, with uniseriate margins of 4–10, and often considerably more, marginal rows of square or upright cells, the cells large and those of the multiseriate parts often almost square and barely procumbent, e.g. in *Aporosa nigricans* Hook. f. and *Protomegabaria stapfiana* Hutch. The larger rays with some, but not pronounced, sheath cells. The cells often containing crystals and sometimes filled with dark deposits; silica present in *Baccaurea* (794). Perforated ray cells numerous in *Aporosa* (358). **Fibres** typically with simple pits and very thick walls; mean length 2·1–2·75 mm. **Latex tubes** reported (938) in the rays of *Hieronyma*.

The following genera from other divisions of the Phyllanthoideae are very similar and can be more satisfactorily fitted into this group than elsewhere.

Putranjiva (Glochidiinae), *Drypetes*, and *Lingelsheimia* (Drypetinae).

These 3 genera are very alike, with characteristic minute intervascular pitting and abundant crystals in the ray cells. They differ from the main group in having rays that, though high, are not more than 2–3 cells wide, with the multiseriate parts limited to relatively small portions of each ray and composed of relatively small, distinctly procumbent cells (Fig. 292 E and F), and in the pits between vessels and ray cells, which are round and similar in size to the intervascular pitting. In *Drypetes* scalariform plates are rare in some species and the parenchyma is sometimes more definitely banded, e.g. in *D. macrophylla* (Bl.) Pax et K. Hoffm. and *D. pendula* Ridl.

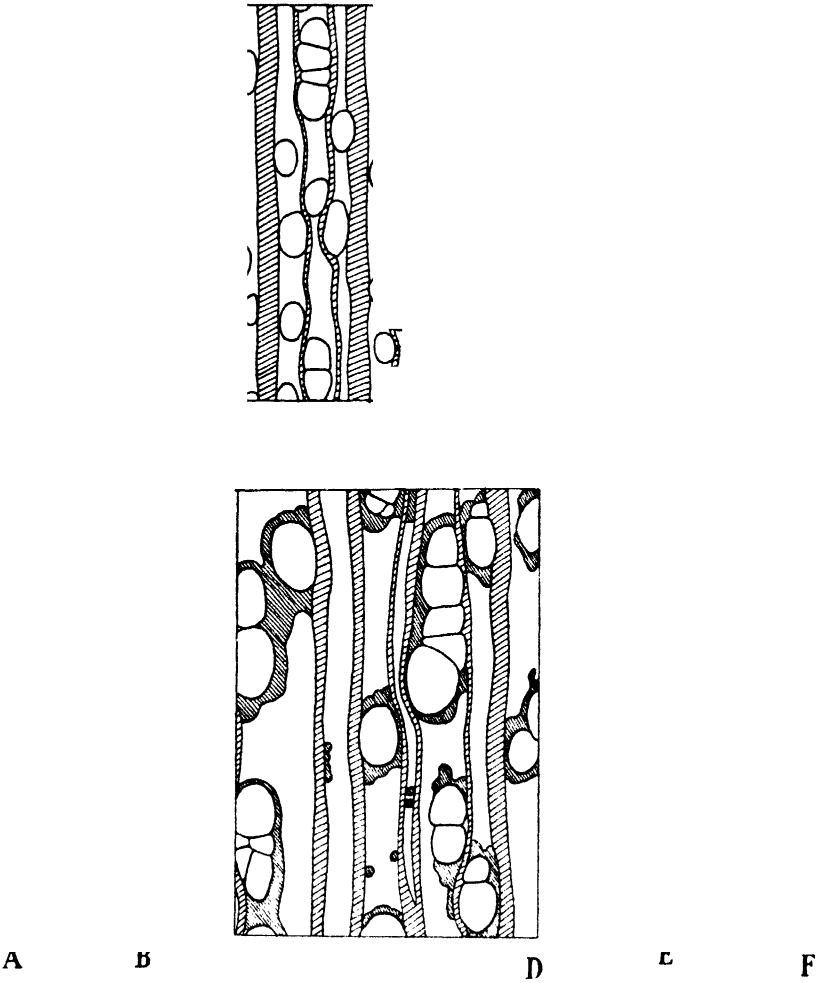


FIG. 293. *EUPHORBIACEAE—PHYLLANTHOIDEAE*. Group B
A, *Cleistanthus myrixanthus* Kurz. B, *Glochidion lanceolatum* Hayata. C, *Antidesma fallax* Müll. Arg. D, *Bridelia micrantha* Baill. E, *B. retusa* Spreng. F, *Antidesma fallax* Müll. Arg.

Amanoa and *Actephila* (Amanoinae).

Amanoa is very similar to the main type, except that the rays are not more than biseriate. *Actephila* appears from descriptions (376) to resemble the main type very closely, including the large rays, but to lack scalariform perforation plates; on the other hand, Solereder described it as having septate fibres.

Aextoxicon punctatum Ruiz. et Pav., if it is correctly placed in the Euphorbiaceae, clearly belongs to this group, where it fits very well; it has scalariform perforation plates with many fine bars and scalariform to opposite intervascular pitting; the vessels are often in clusters, with a slight tangential grouping and there is some tendency to ring-porousness.

Paradrypetes. From the description by Milanez (1520) of *P. illicifolia*, this genus would appear to fit into this group.

(*b*) *Group B* (*Glochidion Type*) (Fig. 293)

Phyllanthoideae:

Antisdesminae p.p.: *Antisdesma*, *Aporosella*, *Hymenocardia.*
Bischoffiinae: *Bischoffia.*
Glochidiinae: *Glochidion.*
Phyllanthinae: *Phyllanthus* (*Securinega*).

Crotonoideae:

Acalypheae: *Acalypha.*

Vessels typically small to moderately small (25–100 μ mean tangential diameter) but moderately large (100–200 μ) in *Bischoffia* and *Glochidion*; solitary and in multiples of 2 or 3 cells or sometimes 4; mostly 20–40 per sq. mm., about 6 per sq. mm. in *Bischoffia.* Spiral thickening reported (1851) in *Glochidion* (1851) and *Securinega* (*Halliophytum*) (938). Perforations typically simple, but scalariform in *Securinega* (*Chascotheca*) and with some scalariform plates, according to Solereder, in *Antidesma*, *Bischoffia*, and *Hymenocardia*, and, according to Janssonius (1154), in *Bridelia.* Intervascular pitting alternate, moderately large in *Antidesma*, *Bischoffia*, and *Phyllanthus*, small in *Acalypha* and *Hymenocardia*, and minute in *Aporosella*, *Glochidion*, and *Securinega*; pits to ray cells large, almost simple, elongated, and often scalariform, except in *Securinega* (*Chascotheca*) and *Glochidion.* Tyloses and solid deposits sometimes present. Mean member length 0·5–1·0 mm. **Parenchyma** typically absent or limited to rare cells touching the vessels. **Rays** of 2 distinct sizes in *Antidesma*, *Aporosella*, *Bischoffia*, and some species of *Glochidion*; typically up to 4–11 cells wide, but not more than 3 cells wide in *Chascotheca*, *Glochidion* p.p., *Hymenocardia*, and *Phyllanthus*; the larger rays often up to about 2 mm. high, but commonly dissected into shorter units; uniseriate rays numerous but often moderately low; 5–17 rays per mm., fewest in *Aporosella*, *Bischoffia*, and some species of *Phyllanthus*; markedly heterogeneous (Kribs's Type I) often with 10 or more marginal rows of square or upright cells, except in *Aporosella* and *Bischoffia*, and often with sheath cells. Cells commonly filled with dark deposits; with numerous crystals in *Acalypha*, *Hymenocardia*, and *Phyllanthus* p.p.; Janssonius (1154) refers to druses in the upright cells of *Acalypha caturus* Bl.; silica reported (794) in *Antidesma* and *Phyllanthus*. Perforated ray cells present in *Bridelia* and *Drypetes* (358). **Fibres** septate;[1] with simple pits that are more numerous on the radial than on the tangential walls; with moderately thick walls, except in some species of *Acalypha*, *Aporosella*, and *Glochidion*. Janssonius (1154) notes the occurrence of single crystals in the fibres of *Bridelia* and *Glochidion*. Mean length 1·1–2·2 mm. The development of **growth rings** in Java has been investigated by Coster (481) in *Acalypha* and *Phyllanthus*.

---

[1] Solereder refers to septate fibres in *Cluytiandra*, *Discocarpus*, and *Sauropus*; these genera may therefore belong to this group, but no material was available for the examination of other features.

Bridelia and *Cleistanthus* (Bridelieae).

Bridelia and *Cleistanthus* should possibly be placed in this group, as is done by Janssonius (1154). He, however, notes that they are distinguished by their aqueous extracts, which contain tannin, except in *C. sumatrus* Müll. Arg., and the existence of some further points of difference suggests that they should be distinguished from the other genera of the group. The intervascular pitting is small in *Bridelia* and minute in *Cleistanthus*, and the latter has minute, circular pitting between vessels and rays; in both there is definite paratracheal parenchyma, which is sometimes moderately abundant in *Bridelia*, e.g. in *B. micrantha* Baill. (Fig. 293 D), and there are usually some scattered cells (often crystalliferous) in *Bridelia*. The rays are not of 2 distinct sizes and tend to be shorter and much less markedly heterogeneous, particularly in *Bridelia*, rays with several marginal rows being exceptional. In both genera the rays commonly contain crystals. The parenchyma strands are often of only 4 cells. Bailey (78) notes vestured pits in the Euphorbiaceae in the Bridelieae only.

(*c*) *Other genera of the Phyllanthoideae*

Androstachys, *Breynia*, *Dissiliaria*, *Longetia*, *Mischodon*, *Oldfieldia*, *Petalostigma*, *Piranhea*, *Savia*, *Uapaca*.

Vessels typically very small (less than 50 μ mean tangential diameter), but rather larger (50–100 μ) in *Oldfieldia africana* Benth., and more than 100 μ in *Breynia*, *Longetia*, *Petalostigma*, and *Uapaca*; solitary and in radial multiples of 2 or 3 cells and often with multiples of 4 or more cells, but tending to be exclusively solitary in *Androstachys*, *Longetia*, and *Mischodon*; mostly 20–40 per sq. mm., fewer in *Breynia*, *Oldfieldia*, *Piranhea*, and *Uapaca*, more numerous in *Androstachys* and *Savia*. Perforations typically simple, but Solereder refers to scalariform plates in *Sauropus* and *Savia*. Intervascular pitting alternate and small to minute, except in *Uapaca* in which it is large; pits to ray and wood parenchyma mostly similar to the intervascular pitting, but larger in *Longetia* and *Uapaca*. Tyloses observed in *Breynia*, *Dissiliaria*, *Petalostigma*, and *Savia*. **Parenchyma** in continuous uniseriate bands in *Breynia*, with widely spaced, possibly terminal, bands in *Dissiliaria* and in relatively broad bands, 2–3 cells wide, in *Piranhea*; limited to a few cells round the vessels in *Androstachys*; with moderately abundant paratracheal parenchyma and some scattered cells in *Uapaca*; scattered among the fibres as isolated strands or short uniseriate lines in the other genera; and with a tendency for the scattered cells to be associated with the vessels in *Oldfieldia*. Sometimes with chambered crystals. **Rays** most commonly 2–3 cells wide; exclusively uniseriate only in *Androstachys* and *Breynia*, and up to 4 cells wide or more in *Longetia*, *Petalostigma*, *Savia*, and *Uapaca*; uniseriate rays usually moderately numerous and low to moderately high; rays most commonly 12–22 per mm., fewer in *Androstachys*, *Oldfieldia*, and *Uapaca*; heterogeneous, commonly with more than 10 marginal rows in several genera.

Crystals often present. **Fibres** mostly with simple pits and thick walls, but with small bordered pits in *Longetia* and large, distinctly bordered pits in *Androstachys*; with a few septate fibres in *Uapaca*. Besson (186) shows a very high percentage of ash and of silica in *Uapaca*.

II. CROTONOIDEAE[1] (Figs. 294 and 295 L–P)

Vessels mostly moderately small (50–100 μ mean tangential diameter) to medium-sized (100–200 μ), about 50 μ or less in some species of *Actinostemon*, *Agrostistachys*, *Celaenodendron*, *Codiaeum*, *Dimorphocalyx*, *Euphorbia*, *Fontainea*, *Gymnanthes*, *Lasiocroton*, *Leucocroton*, *Pausandra*, *Pogonophora*, *Pycnocoma*, and *Sebastiania*, large (more than 200 μ) in some species of *Alchornea*, *Alchorneopsis*, *Cunuria*, *Elateriospermum*, *Endospermum*, *Hevea*, *Hura*, *Jatropha*, *Joannesia*, *Ricinodendron*, and *Sapium*; typically solitary and in numerous multiples of 2 or 3 cells, and often with multiples of 4 or more cells; sometimes with a radial or oblique pattern, e.g. in *Agrostistachys*, *Aparisthmium*, *Claoxylon*, *Codiaeum*, *Necepsia*, *Ptychopyxis*, *Pycnocoma*, *Senefeldera*, and *Trigonostemon*; very commonly fewer than 5 per sq. mm. and seldom more than 17 per sq. mm. except in some of the species with very small vessels. Reported to be sometimes ring-porous in *Aleurites* (938) and *Mallotus* (1851), and occasionally to have spiral thickening in *Alchornea*, *Cleidion*, *Elateriospermum* (938), *Mallotus*, *Pogonophora* (938), and *Trewia*. Perforation plates typically simple, but exclusively scalariform in *Microdesmis*; Solereder refers to the occurrence of some scalariform plates[2] in *Adenocline*, *Agrostistachys*, *Alchornea*, *Bennetia*, *Cnesmone*, *Hevea*, *Hura*, *Mallotus*, *Manihot*, *Mercurialis*, *Ostodes*, *Pachystroma*, *Pausandra*, *Pogonophora*, and *Tragia*. Janssonius (1154) refers to the occurrence of occasional scalariform plates in some species of *Claoxylon* and *Macaranga*, and Record and Hess (1886) to scalariform plates in *Conceveiba*. Intervascular pitting typically medium-sized to large, often with the apertures small and not extending to the borders; apertures and borders often elongated and almost scalariform in *Agrostistachys*; pits very small to minute in some species of *Celaenodendron*, *Claoxylon*, *Codiaeum*, *Maprounea*, *Pogonophora*, *Trigonostemon*, and *Wetria*; pitting opposite or scalariform in some species of *Euphorbia* and, according to Record (1886), in *Pedilanthus* (*Cubanthus*). Pits to ray and wood parenchyma commonly large and elongated and often scalariform, particularly in the Acalypheae, but with circular pits similar to the intervascular pitting in the following: Acalypheae—*Adelia*, *Alchorneopsis*, *Blumeodendron*, *Cleidion*, *Homonoia*, *Lasiocroton*, *Leucocroton*, *Mallotus* p.p., *Pycnocoma*, and *Trewia*; Crotoneae—*Croton*; Schizophoreae—*Sumbavia*; Pereae—*Pera*; Cluytieae—*Codiaeum*, *Dimorphocalyx*, *Fontainea*, *Jatropha*, *Ostodes*, and *Trigonostemon*; Gelonieae—*Chaetocarpus*, *Gunuria*, *Elateriospermum*, *Endospermum*, *Gelonium*, *Neoscortechinia*, *Omphalea*, and *Tetrorchidium*; Hippomaneae—*Actinostemon*, *Excoecaria*, *Sapium* p.p., and *Sebastiania*; Joannesieae—*Hevea*, *Joannesia*; and in *Celaenodendron*. Tyloses often present and occasionally sclerotic, e.g. in *Agrostistachys*, *Chaetocarpus* (1886), *Elateriospermum* (434), *Pera*, and *Pogonophora*;

---

[1] Excluding *Acalypha*, which has been described in Group B (Glochidion Type) of the Phyllanthoideae, but including *Celaenodendron* and *Ptychopyxis*, genera *incertae sedis*.

[2] These scalariform plates appear to be rare or are possibly confined to the early rings, as they were not observed in any of the material examined, which included many of these genera.

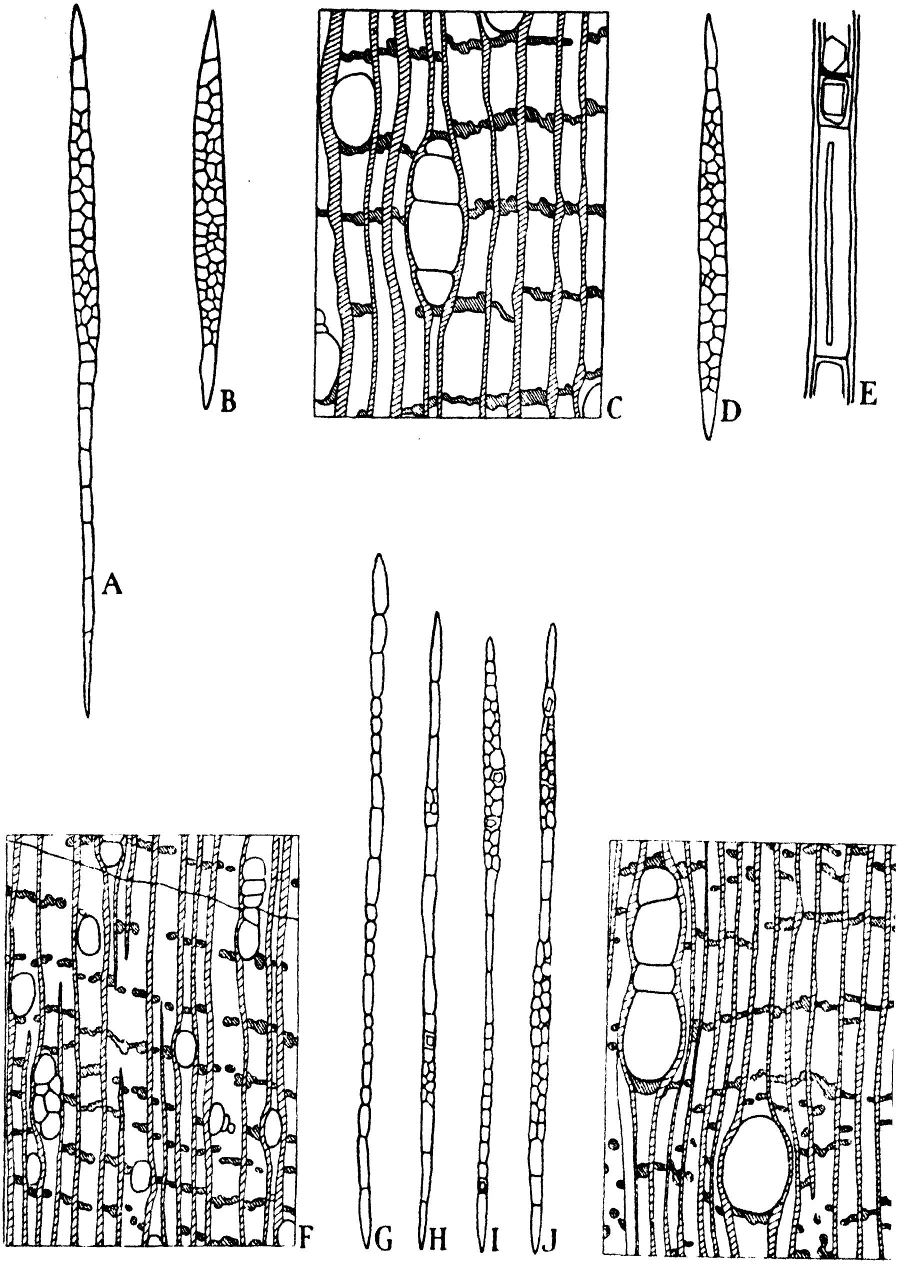


FIG. 294. *EUPHORBIACEAE—CROTONOIDEAE*

A, *Cunuria* sp. B, *Chaetocarpus castanocarpus* Thw. C, *C. castanocarpus* Thw. D, *Cunuria s* E, *Elateriospermum tapos* Blume. Sclerotic parenchyma × 200. F, *Grossera vignei* Hoyle. G, *Gavarret terminalis* Baill. H, *Grossera vignei* Hoyle. I, *Mallotus acuminatus* Müll. Arg. J, *Macaranga bart* Müll. Arg. K, *Gavarretia terminalis* Baill.

containing druses in *Macaranga tanarius* Müll. Arg. (1154); solid deposits sometimes present. Mean member length usually 0·3–0·85 mm., but Kribs (1283) gives 1·4 for *Sapium*.

Parenchyma typically abundant and apotracheal. Most commonly as scattered cells or short, irregular, uniseriate lines (Fig. 295 N). In very distinct, continuous, uni- to biseriate bands (Fig. 294 C) in *Chaetocarpus*, *Cunuria*, *Elateriospermum*, *Hevea*, and *Ptychopyxis*, and in moderately continuous bands (Figs. 294 F and K) in some species of *Anthostema*, *Coccoceras*, *Coelodepas*, *Conceveiba*, *Croton*, *Dodecastigma*, *Excoecaria*, *Fontainea*, *Gavarretia*, *Grossera*, *Hura*, *Joannesia*, *Maprounea*, *Neoscortechinia*, *Pausandra*, *Pera*, *Pimeleodendron*, *Sagotia*, *Sapium*, and *Tetrorchidium*; sometimes with a little paratracheal parenchyma in addition (Fig. 295 O), e.g. in *Aleurites*, *Cleidion*, *Croton*, *Mallotus*, *Mareya*, *Ricinodendron*, and *Ricinus*. Predominantly paratracheal, aliform to confluent (Fig. 295 K), with or without diffuse parenchyma, in *Celaenodendron* and *Pogonophora*. In broad irregular bands, mostly connecting the vessels, in *Manihot*. Terminal bands not usually distinguishable, but distinct in *Agrostistachys*, *Necepsia*, *Pogonophora*, and *Pycnocoma*. Diffuse parenchyma very abundant and occupying more space than the fibres in *Ricinodendron rautanenii* Schinz. Often containing chambered crystals. Strands most commonly of 8 cells, sometimes fewer (4 cells), particularly in the Hippomaneae, e.g. in *Excoecaria*, *Hippomane*, *Sapium*, and *Sebastiania*, and in *Hevea*. With characteristic sclerotic cells in *Chaetocarpus*, *Cunuria*, and *Elateriospermum* (Fig. 294 E). Silica occasionally present (794). **Rays** typically up to 2–3 cells wide or wholly uniseriate, sometimes up to 4–5 cells wide in the Acalypheae, e.g. in some species of *Claoxylon*, *Cleidion*, *Mareya*, and *Ricinus*, and in *Acidocroton* (1886), *Aparisthmium* (1886), *Chaetocarpus*, and *Omphalea* (1886), wholly uniseriate or with only rare biseriate rays in Joannesieae—*Joannesia*; Acalypheae—*Adelia*, *Alchornea*, *Caryodendron*, *Coccceras*, *Conceveiba*, *Conceveibastrum*, *Gavarretia*, *Macaranga* p.p., *Mallotus* p.p., *Pycnocoma*; Gelonieae—*Gelonium* p.p.; Pereae—*Pera*; Cluytieae—*Codiaeum*, *Ricinodendron*; Hippomaneae—all the genera examined, i.e. *Actinostemon*, *Excoecaria*, *Gymnanthes*, *Hippomane*, *Homolanthus*, *Mabea*, *Maprounea*, *Pimeleodendron*, *Sapium*, *Sebastiania*, and *Senefeldera*, but with some biseriate rays in *Pimeleodendron*; Euphorbieae—*Anthostema*, *Euphorbia* p.p., and in *Dodecastigma*; typically more than 1 mm. high, but lower in the following: Crotoneae—*Croton*; Acalypheae—*Adelia*, *Mallotus* p.p., *Necepsia*, *Pycnocoma*; Joannesieae—*Hevea*, *Joannesia*; Manihoteae—*Manihot*; Cluytieae—*Codiaeum*, *Fontainea*, *Ricinodendron*, *Sagotia*; Gelonieae—*Chaetocarpus*, *Cunuria*, *Elateriospermum*, *Gelonium*, *Omphalea*; Pereae—*Pera*; Hippomaneae—*Dactylostemon*, *Excoecaria*, *Gymnanthes*, *Hura*, *Maprounea*, *Sapium*, *Sebastiania*, *Senefeldera*; Euphorbieae—*Anthostema*, *Euphorbia*, and in *Ptychopyxis*; in woods with multiseriate rays the uniseriates usually high and numerous, except in some of the Joannesieae and Gelonieae, and composed of upright cells or mixed upright and procumbent cells. Aggregate rays observed in *Necepsia* and *Pseudagrostistachys*. Rays 7–25 per mm., mostly 11–21; markedly heterogeneous (Kribs's Types I, II, and III), typically with 4 or more, and commonly with 10 or more, marginal rows of upright cells and with 2 or more small multiseriate portions per ray (Fig. 295 E and I); marginal rows few in some species of *Celaenodendron*, *Croton*, *Joannesia*, *Manihot*, and

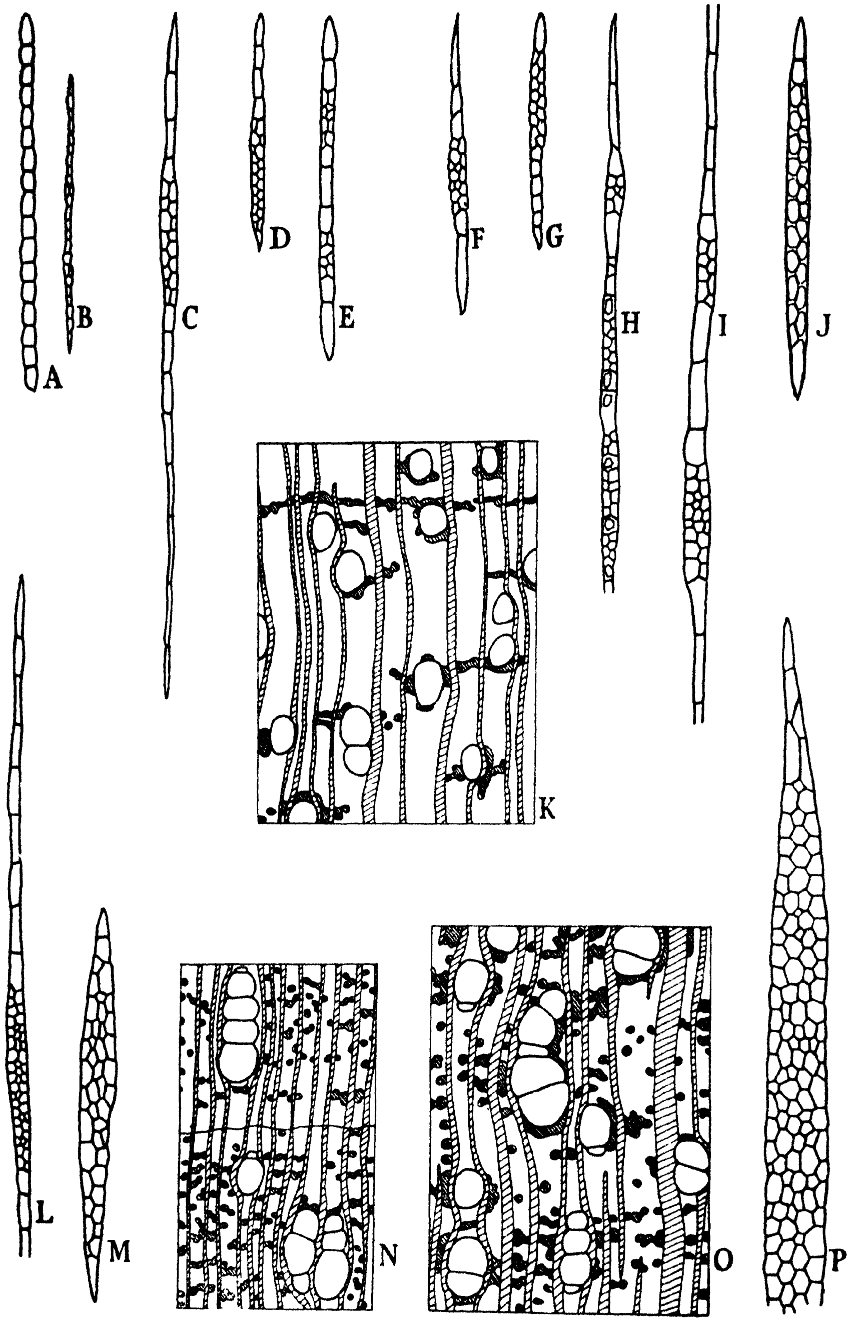


FIG. 295. *EUPHORBIACEAE—MISCELLANEOUS*, A–K; *CROTONOIDEAE*, L–P

A, *Ricinodendron rautanenii* Schinz. B, *Excoecaria africana* Müll. Arg. C, *Tetrorchidium didymostemon* (Baill.) Pax et Hoffm. D, *Croton oblongifolius* Roxb. E, *Hevea discolor* Spruce. F, *Mischodon zeylanicus* Thw. G, *Oldfieldia africana* Benth. et Hook. f. H, *Neoscortechinia arborea* Pax et Hoffm. I, *Claoxylon cuneatum* J. J. Smith. J, *Endospermum malaccense* Benth. K, *Pogonophora schomburgkiana* Miers. L, *Cleidion javanicum* Blume. M, *Ricinus communis* Linn. N, *Adelia triloba* Hemsl. O, *Mareya* '*micrantha*'. P, *M.* '*micrantha*'.

Ricinus; in woods with uniseriate rays only, the cells varying from all square or upright, e.g. in *Euphorbia* p.p., *Hevea*, and *Tetrorchidium*, to all procumbent cells, e.g. in *Excoecaria*, *Hippomane*, *Hura*, and *Ricinodendron* (Fig. 295 A and B), but most commonly markedly heterogeneous (Fig. 294 G). Commonly containing crystals, particularly in species without crystalliferous strands of parenchyma, and often with dark, gummy contents; Janssonius (1154) reports druses in *Macaranga rhizinoides* Müll. Arg. Gonggrijp (794) reports silica in some species in *Phyllanthus* and *Sapium*. Sometimes with rounded cells and marked intercellular spaces, e.g. in *Endospermum* (Fig. 295 J), *Joannesia*, *Macaranga*, *Ricinodendron*, and several genera of the Hippomaneae. Perforated ray cells reported (358) in *Blachia*, *Microdesmis*, and *Necepsia*. **Fibres** typically with small pits, more numerous on the radial than on the tangential walls; the pits sometimes with small borders, e.g., according to Solereder, in Acalypheae—*Cleidion*, *Cnesmone*, *Mercurialis*, and *Trewia*; Cluytieae—*Galearia*, *Jatropha*, *Ostodes*, and *Pausandra*; Gelonieae—*Adenocline*, *Chaetocarpus*, and *Gelonium*; and Hippomaneae—*Actinostemon*, *Adenopeltis*, *Colliguaja*, *Maprounea*, and *Stillingia*; to these may be added *Caryodendron* (2427), *Codiaeum*, *Endospermum*, *Nealchornea*, and *Ricinodendron*; occasionally with large, distinct borders, e.g. in *Conceveibastrum*, *Macaranga*, and *Microdesmis*. Walls usually moderately thin, but sometimes thick and then often with a mucilaginous layer. Septate in *Acalypha*[1] (see Phyllanthoideae Group B) and, according to Record and Hess (1886), in *Acidocroton*; Janssonius (1154) refers to rare septate fibres in *Aleurites*. Mean length 0·7–1·65 mm. **Latex tubes** reported by Record and Hess (1886) in some of the rays of *Cunuria* (Anomalocalyx), *Hippomane*, *Nealchornea* (Glycydendron), and *Sebastiania*, and by Heimsch (938) in *Dalechampia*, *Euphorbia*, and *Hippomane*. **Intercellular canals**: small radial canals reported (938, 1851) in *Alchornea*, *Baloghia*, *Euphorbia*, and *Homalanthus*, and traumatic axial canals in *Croton* (183). Radial channels, often large and suggesting remnants of leaf traces (cf. Apocynaceae, 'Latex traces', p. 912), reported (1886) in some species of *Alchornea*, *Conceveiba*, *Conceveibastrum*, *Croton*, *Euphorbia*, *Gavarretia*, *Hura*, *Mabea*, *Pera*, *Sapium*, and *Senefeldera*. The development of **growth rings** in Java has been investigated by Coster (481) in *Hevea* and *Jatropha*.

ROOT

The following characters recorded for *Euphorbia corollata* Linn. by Holm (994). Cork thick, homogeneous. Secondary cortex broad, amyliferous. Phloem scanty. Xylem in the form of narrow, radiate groups, including reticulate vessels and surrounded by fibres, the xylem groups being separated by broad, parenchymatous rays. Laticiferous canals in the secondary cortex. Holm (1051) has also recorded the following information concerning *Stillingia sylvatica* Garden. Thick roots consisting of cork, secondary cortex, well-developed xylem and no pith. Fibres present in the primary, but none seen in the secondary, phloem. Numerous laticiferous vessels in the secondary cortex. According to Griebel (820) the starch of *Manihot utillissima* Pohl. is stored chiefly in the xylem of the fleshy roots. See also under 'Economic Uses'.

---

[1] *Acalypha indica* L., according to the description by Kanehira (1206), lacks septate fibres and its anatomy generally appears typical of the Crotonoideae and not of Group B of the Phyllanthoideae.

Roots of *Euphorbia radians* Benth. are fleshy and resemble strings of sausages, covered with brownish-black periderm and extending 30–75 cm. below the ground. Transverse sections through the constrictions in the roots exhibit, according to Reiche (1910), radiating groups of large vessels, fibres and parenchyma, separated by broad parenchymatous rays. Xylem surrounded by zones of cambium and phloem. Transverse sections through the swollen portions of the root show irregularly distributed groups of vessels embedded in parenchyma filled with typical euphorbiaceous starch. **Thorns** which are morphologically roots, with apical root caps, occur on the trunks of *Bridelia pubescens* Kurz. according to Parija and Misra (1653). These structures, which are polyarch when young, gradually become embedded in the trunk during secondary thickening. Root thorns grow best in a humid atmosphere, and are stimulated by the absence of light, their maximum development being attained if they are covered with soil.

ANOMALOUS STRUCTURE

Intraxylary phloem, accompanied by fibres in some species, recorded in *Alchornea*, *Coelobogyne*, *Conceveiba*, *Croton* (most species but not always present in the section *Astraea*), *Crotonopsis*, *Eremocarpus*, *Julocroton*, *Lepidoturus*, *Mabea*, *Mallotus subulatus* Müll. Arg. (but not in other species of this genus), *Pera*, *Sebastiania* (some species), *Senefeldera*. **Cambiform tissue,** apparently devoid of sieve tubes, occurs as a continuous sheath or in the form of strands around the periphery of the pith, in most Crotonoideae and Ricinocarpoideae, according to Pax and Hoffmann (1673). Cambiform tissue around the pith also occurs in *Euphorbia radians* Benth. according to Reiche (1910). Normal structure recorded in many lianes belonging to the family, but secondary strands of xylem and phloem in the pericycle, as well as **interxylary phloem** embedded in thin-walled parenchyma, recorded in certain species of *Dalechampia*. Interxylary phloem has also been recorded in *Lepidoturus*. Centric **medullary bundles** (Fig. 291 H) with central phloem sometimes present in *Phyllanthus* and *Ricinus*. For further details concerning the lepto-centric bundles in the upper part of the stem of *Ricinus* see the article by Alexandrov and Alexandrova (17).

ECOLOGICAL ANATOMY

Variations in the structure of *Ricinus communis* Linn., grown under different conditions of light intensity and soil moisture, have been described by Penfound (1685). The ecological anatomy of several species of *Euphorbia* and one of *Glochidion* has been described by Kienholz (1236) and Zemke (2505).

TAXONOMIC NOTES

(i) FROM GENERAL ANATOMY

It is generally recognized by taxonomists that the Euphorbiaceae is a family of polyphyletic origin. It is not surprising, therefore, to find a lack of anatomical homogeneity throughout the group, and that rather diverse affinities have been proposed for various of its members.

Dehay's (557) work on the vascular structure of the midrib and petiole of a considerable number of Euphorbiaceae has led to interesting conclusions. Thus the well-known resemblances between the Euphorbiaceae on the one hand and the Malvaceae, Tiliaceae, and related families on the other are supported by similarities in petiolar structure. The close relationship between the Buxaceae and Euphorbiaceae is similarly confirmed. The agreement between the Euphorbiaceae and the Urticales was found to be less comprehensive, although Dehay lists similar species from both groups. Comparing the Euphorbiaceae with the Artocarpoideae, similarities were found between *Mallotus japonicus* (Thunb.) Müll. Arg. and *Antiaris toxicaria* Lesch. as well as between *Putranjiva roxburghii* Wall. and *Cudrania javanensis* Trec. *Pogonophora schomburgkiana* Miers of the Euphorbiaceae was also found to resemble *Anomocarpus amazonicus* Ducke of the Moroideae. Agreement with the Urticaceae is shown by the similarity of *Endospermum chinensis* Benth. to *Myriocarpa*, of *Hieronyma oblonga* (Tulasne) Müll. Arg. to *Villebrunia integrifolia* Gaudich, and of species of *Anthostema* and *Stillingia* to *Urera*. Resemblances to the Conocephaloideae are indicated by the similarity of *Macaranga* and *Uapaca* to *Coussapoa latifolia* Aubl. and of *Manihot* and *Ricinus* to *Musanga smithii* R. Br. Whilst the floral and petiole structure in different genera of Euphorbiaceae do not run on strictly parallel lines, it is noteworthy that *Wielandia*, the genus regarded by Baillon as having a central type of floral structure for the family, also exhibits the type of vascular structure which Dehay considers to be basic for the family.

Moyer (1567), who examined the iso-electric points and electrophoretic mobility curves for the latex particles of 21 species of *Euphorbia*, found these physical qualities to be constant and of diagnostic value for each species, provided that healthy material was investigated. Furthermore, the mobility curves for the latex particles can be arranged in groups corresponding to the taxonomic divisions of the genus.

Perry (1699), who investigated the chromosome numbers in relation to the phylogenetic relationships of the Euphorbiaceae, was unable to find any evidence in favour of the wide separation of *Aleurites* from *Jatropha* adopted by Pax and Hoffmann (1673) in their monograph of the family. Perry's cytological observations were found to support Bentham and Hooker's treatment of the family. Perry also states that the number, size, and certain morphological differences of the chromosomes suggest that the *Euphorbia* complex could be broken up into several genera.

Milanez (1520) states that the anatomy of *Paradrypetes* agrees very closely with that of the Drypetinae.

Varossieau (2324) discovered no convincing evidence, from the anatomy of the vegetative organs, that *Eucommia* (Family Eucommiaceae, p. 31) is closely related to the Euphorbiaceae.

Trumke (2286) found anatomical characters to be less valuable than might have been expected for the identification of the succulent Euphorbias, or as a means of dividing the species into groups.

(ii) FROM WOOD STRUCTURE

PHYLLANTHOIDEAE

Group A. Aporosa Type (Fig. 292)

The group is primarily composed of genera of the Antidesminae, but does not include all of these, *Antidesma*, *Aporosella*, and *Hymenocardia* falling into

Group B (Glochidion Type). A similar division occurs in the Glochidiinae, *Putranjiva* fitting into Group A and *Glochidion* into Group B, which, incidentally, also includes *Phyllanthus*, with which *Glochidion* was once merged.

Janssonius (1154), investigating a more limited number of genera, distinguished a similar group, in which he placed *Aporosa*, *Baccaurea*, *Drypetes* (*Cyclostemon*), and *Putranjiva*.

Aextoxicon fits into this group without difficulty. Being of a very unspecialized type, it also has many features in common with the Aquifoliaceae, and with the unspecialized members of the Icacinaceae, e.g. *Apodytes*, near which some authors would place it. Though it does not appear to fit quite as well there, the differences from these families are too slight to render any such affinity improbable.

Group B. Glochidion Type (Fig. 293)

This group, which is distinguished mainly by the presence of septate fibres and the absence of parenchyma or its limitation to a few cells round the vessels, is not entirely homogeneous in all its details, the most striking differences being in vessel pitting and ray type.

Antidesma, *Bischoffia*, and *Phyllanthus* are very similar to certain genera of the Flacourtiaceae, e.g. *Calancoba*, *Erythrospermum* and *Kiggelaria*: *Acalypha*,[1] *Aporosella*, *Glochidion*, and *Hymenocardia*, with small intervascular and vessel-ray pitting, suggest the group of genera in the Flacourtiaceae that were formerly included in the Samydaceae. *Bridelia* and *Cleistanthus* closely resemble some genera of the Samydaceae, e.g. *Homalium*.

Janssonius (1151, 1154) notes also a similarity between the structure of the woods of this group and that of the Violaceae (*Alsodeia*), the Burseraceae, and *Siphonodendron* of the Celastraceae. They also bear a close resemblance to a group of woods in the Apocynaceae (see p. 914).

Spondianthus, if it is correctly placed in the Euphorbiaceae, falls into this group on account of its septate fibres; it differs from the other genera, but in the combination of its features rather than by the presence or absence of any one. Thus it has large rays typical of Group A, the intervascular pitting is similar to that of *Antidesma*, and the occurrence of vasicentric parenchyma suggests *Bridelia*; only the pitting between vessels and rays cannot be matched, being large and usually circular.

Other Genera of the Phyllanthoideae

The genera that cannot be fitted into Groups A and B are a heterogeneous group. *Androstachys*, *Oldfieldia*, *Piranhea*, and *Uapaca* are each outstanding and can neither be satisfactorily grouped together nor fitted into any of the other groups of the family.

Longetia has many features in common with the Aporosa Type, but differs in having solitary vessels, simple perforations, narrower rays, and fibres with distinctly bordered pits.

---

[1] There is considerable discrepancy between various descriptions of *Acalypha* spp. Some (1154, 1851, 1854) agree with the material examined, on the basis of which *Acalypha* has been placed with Group B of the Phyllanthoideae, in others (1206, 2430) the woods described appear to be typical of the Crotonoideae.

Breynia, *Dissilaria*, *Mischodon*, *Petalostigma*, and *Savia* appear to have more in common with the Crotonoideae than with Groups A or B of the Phyllanthoideae.

CROTONOIDEAE (Figs. 294 and 295)

Chaetocarpus, *Cunuria*, and *Elateriospermum* of the Chaetocarpinae are very alike, including the occurrence of unusual sclerotic parenchyma cells, and form a homogeneous group (Fig. 294 A–E). From descriptions, *Nealchornea*, of the same sub-tribe, would appear to fit well into the group, though with some points of difference.

All the genera examined from the other sub-tribes of the Gelonieae show a general similarity, particularly as regards parenchyma, which is one of the most striking differences between this group and the other Crotonoideae, but differ in other features, particularly type of ray. These genera are: Geloniinae —*Gelonium*, *Neoscortechinia*; Endosperminae—*Endospermum*; Tetrorchidiinae —*Tetrorchidium*.

Thus the group could be made to correspond with the tribe Gelonieae quite conveniently. But the number of characters that would remain constant throughout would be much reduced, and, on the basis of these alone, one could not logically exclude yet other genera, such as *Hevea* and *Joannesia*.

Microdesmis puberula Hook. f. is unlike any of the other Euphorbiaceae. *Pogonophora schomburgkiana* Miers, of the same sub-tribe Galeariinae, is also odd and should probably be excluded.

Androstachys of the Phyllanthoideae resembles the above 2 genera in many respects.

Acalypha has been placed in Group B (Glochidion Type).

Ricinodendron is rather exceptional, with its large and abundant parenchyma cells and few, large vessels.

The Hippomaneae make a fairly distinct group, but *Pimeleodendron* is exceptional in several minor respects.

Janssonius states that *Blumeodendron*, *Mallotus*, and *Trewia* are so similar that they might be one genus.

Ptychopyxis fits without difficulty into the Crotonoideae, being similar in most respects to the genera of the Gelonieae. *Manihot* is exceptional in having broad bands of parenchyma.

Celaenodendron has been described with the Crotonoideae in preference to the Phyllanthoideae, but does not really fit well there, having aliform to confluent parenchyma (cf. *Pogonophora*).

Economic Uses

It is impossible to describe fully all of the many uses to which members of the Euphorbiaceae have been put. The family includes edible and poisonous species, many of which have been, or still are, used to some extent in medicine, whilst others yield rubber or oils.

The most important economic species is the Para Rubber tree (*Hevea brasiliensis* (H. B. et K.) Müll. Arg.), native of the Amazon region, but now extensively cultivated in Ceylon, Malaya, the East Indies, &c. It is well known that the latex is obtained by tapping the bark, in which the latex vessels are chiefly situated. According to Quisumbing (1768) the laticiferous vessels also occur in the pith, leaves, and roots even in seedling plants. The laticiferous vessels are numerous in the inner part of the cortex, less numerous in the outer part of the phloem, whilst in the xylem they are confined to the medullary rays. Laticiferous vessels in the secondary phloem arise from the cambium, the peripheral vessels originating in the primary cortex or as derivatives of the phellogen. Vischer (2336, 2337) describes the laticiferous vessels as being in parallel rows united laterally at infrequent intervals, the vessels in the root and stem being directly connected. There has been disagreement concerning the relationship of the latex yield to variations in the anatomical structure of the laticiferous system. Vischer (2336, 2337) found a correlation between the number of laticiferous vessels in the cortex ('Rinde') and the yield of latex. The same author also established that, in grafted specimens, the yield of latex is not controlled by the stock, although the laticiferous vessels in stock and scion were found to be directly connected. According to Ashplant (46), all high-yielding plants have laticiferous vessels of appreciably wider diameter than have low-yielding specimens. By measuring the diameter of the laticiferous vessels in the petioles of seedlings, Ashplant maintained that low-yielding specimens could be eliminated in commercial practice whilst still young. More recently this view has been supported by Gunnery (850). Frey-Wyssling (711), who also investigated this subject, found that, although many high-yielding plants have latex elements of larger diameter than have those which give a lower yield, the correlation is not absolute. This is partly due to physiological complications. To the present writer it seems that satisfactory separation of high- and low-yielding plants could be secured in commercial practice only by employing well-trained, experienced microscopists, if at all.

'Burrs' or 'nodules' occur in the cortex of *Hevea brasiliensis*. These pathological structures, which have been examined by Bryce (301), start as small bodies about the size of a pea. They later become as large as a hen's egg, or several nodules may fuse to form an irregular mass. Nodules are formed around some of the latex vessels, around accumulations of coagulated latex, or occasionally in areas of cortex from which latex may be entirely absent. Their formation is due to a physiological disturbance which is not understood. The 'burrs' occur more frequently in tapped than in untapped trees. Globular shoots, formed from latent buds, also occur embedded in the cortex, but these structures are smaller than the nodules.

Callus formation in *H. brasiliensis* has been investigated by Sharples and Gunnery (2084), whilst the possible protective function of the laticiferous system has been discussed by Sharples (2083). The mode of development of the cork has been studied by Gandrup (740).

Ceara Rubber is obtained in South America from *Manihot glaziovii* Müll. Arg. The latex from the succulent and other types of Euphorbia has not been used commercially as a source of rubber because the latex has a high resin content.

Two of the most important oil-yielding species derived from this family are *Aleurites fordii* Hemsl., from which Tung Oil is obtained in the Far East, and *Ricinus communis* Linn., widely cultivated in the tropics and sub-tropics for the Castor Oil obtained from its seeds. The microscopy of the fibre obtained from the stem of this species has been examined by Iwanowa-Paroiskaja (1128).

Cassava, from which tapioca is prepared, is the starchy substance obtained in the tropics from the roots of cultivated varieties of *Manihot utilissimus* Pohl. According to Griebel (820) the diagnostic characters for Cassava include the reticulate vessels, surrounded by cells with pearly thickenings to the walls; the groups of stone cells, often accompanied by chambered fibres containing solitary crystals. The starch grains, often in aggregates of 2–3 or 4–8, are rounded but flattened on one side. The individual grains include some which are less than 15 μ, but others up to 20 μ or occasionally 35 μ in diameter.

Kamala, which consists of the covering and glandular hairs on the outside of the fruits of *Mallotus philippinensis* (Lam.) Müll. Arg., has been used for dyeing silk, and in medicine as a vermifuge. The unicellular trichomes are thick-walled, and arranged in radiating groups of 2–10. The sub-globular glands, which are 40–100 μ in diameter, consist of numerous, radiately arranged, club-shaped cells containing dark red matter.

Other members of the family with medicinal uses include *Euphorbia hirta* Linn., an Indian annual, of which the whole plant is used; euphorbium, which is the dried latex of *E. resinifera* Berg. from Morocco; Croton Oil, obtained in India and other parts of Asia, from *Croton tiglium* Linn. Cascarilla bark, obtained in the Bahamas from *C. eleuteria* Benn., possesses febrifugal properties. This bark is characterized microscopically by cork cells with thickened outer walls containing small crystals of calcium oxalate; the presence of oil and resin cells and of laticiferous elements; numerous phloem fibres, either isolated or in small strands; numerous cluster and less frequent solitary crystals in the cells of the ground-tissue; uniseriate medullary rays. Copalchi bark, which occurs commercially in larger pieces, is said to be derived from *C. niveus* Jacquin and to be used as a substitute for Cascarilla. The present writer believes that the exact botanical source of these 2 kinds of bark would be worthy of careful reinvestigation.

The microscopical structure of the roots of *Euphorbia corollata* Linn., which possesses medicinal properties resembling those of Ipecacuanha (Family Rubiaceae, see p. 773), has been described by Holm (994) (see under 'Root' on p. 1227). Holm (1051) has also described the structure of *Stillingia sylvatica* Garden., the fusiform roots of which have also been used in medicine. Medicinal properties have also been attributed to other species of *Euphorbia*, and the bark of *Petalostigma quadriloculare* F. v. Müll. has been used in Australia to prepare a febrifuge.

The latex of some members of the family is poisonous, e.g. that which is derived from *Excoecaria agallocha* Linn. causes severe blisters on the skin and irritation to the eyes (Santos 1993). Edible fruits include those of *Phyllanthus emblica* Linn. and *Baccaurea dulcis* (Jack.) Müll. Arg. in the East Indies, *B. sapida* (Roxb.) Müll. Arg. in India, and *Omphalea triandra* Linn. in the West Indies.

Considering the variety of wood anatomy in this family, it is not surprising to find also a considerable range of properties in the timbers. Yet none of the species produces a first-class timber and very few of the woods are even of local importance. Most of the woods are perishable and rather light, and a few, such as Mugongo, *Ricinodendron rautanenii* Schinz, are extremely light and soft and are used for special purposes such as carving; *Endospermum malaccense* Müll. Arg. is reported (574) to be popular for match-sticks in

Malaya and some of the timbers are suitable for packing-cases, e.g. *Excoecaria agallocha* Linn., though many of these are either too scarce or too difficult to season without stain to be much used in practice. At the other extreme there are a few relatively dense and durable timbers, some of which are dark-coloured. For example, species of *Bischofia*, *Cunuria*, *Glycydendron*, *Gymnanthes*, *Hieronyma*, *Hippomane*, and *Oldfieldia* are cited by various authors as the sources of relatively durable or coloured timbers, though small size or lack of adequate supplies render many of them of little importance. In India Bishopwood, *Bischofia javanica* Blume, is a constructional timber of which Pearson and Brown (1679) say that it 'just misses being a really first-class timber, but it is well worthy of attention'. The wood of *Oldfieldia africana* B. et H. f., has been known for a long time in Europe as a hard, tough, and durable timber and Howard (1088) states that it was used in the British Navy for shipbuilding 150 years ago. It does not, however, appear to be of any importance at the present day. Edmondson (623A) has reported that 2 species of *Antidesma* have been found to possess an exceptional degree of resistance to marine borers. In South America *Hieronyma alchorneoides* Fr. Allem. is widely used, particularly for constructional and other outdoor purposes that require a strong, durable timber; it is also occasionally used for furniture (1886). Janssonius (1150) has suggested that the woods of the Phyllanthoideae should be suitable for paper pulp, as they not only possess very long fibres, but also macerate more easily than most woods.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

The following genera are mentioned in the text, but statements about others also occur in the literature. Acalypha,* Acidocroton, Actephila, Actinostemon, Adenocline, Adenopeltis, Adriana, Agrostistachys, Alchornea, Aleurites, Amanoa, Amperea, Andrachne,* Antidesma, Aporosa, Argithamnia, Baccaurea, Bernardia, Bertya, Beyeria, Bischoffia, Breynia, Bridelia, Caperonia, Cephalocroton, Chaetocarpus, Chiropetalum, Chondrostylis, Claoxylon, Cleidion, Cluytia, Cnesmone, Cnidoscolus, Coccoceras, Codiaeum,* Coelodiscus, Colliguaja, Conceveiba, Cordemoya, Croton,* Crotonogyne, Crotonopsis, Dalechampia, Discocarpus, Ditaxis, Drypetes,* Eremocarpus, Erismanthus, Erythrococca, Euphorbia,* Excoecaria, Gelonium, Givotia, Glochidion, Hevea,* Hieronyma, Hippomane, Homonoia, Hura, Hymenocardia, Jatropha, Joannesia, Julocroton, Mabea, Macaranga, Mallotus, Manihot, Manniophyton, Maprounea, Mareya, Mercurialis,* Micrandra, Micrantheum, Microdesmis, Omphalea, Ostodes, Pachystroma, Pausandra, Pedilanthus,* Pera, Petalostigma, Phyllanthus,* Pogonophora, Pseudolachnostylis, Putranjiva, Richeria, Ricinocarpos, Ricinus,* Savia, Sebastiania, Securinega,* Senefeldera, Stachystemon, Stillingia, Symphyllia, Synadenium, Tetrorchidium, Tragia, Trewia, Trigonostemon, Uapaca, Wielandia.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Phyllanthoideae

Actephila, Aextoxicon, Amanoa, Androstachys, Antidesma, Aporosa, Aporosella, Baccaurea, Bischoffia, Breynia, Bridelia, Cleistanthus, (Cluytiandra), Dicoelia, (Discocarpus), Dissiliaria, Drypetes, Glochidion, Hieronyma, Hymenocardia, Lingelsheimia, Longetia, Maesobotrya, Mischodon, Oldfieldia, (Paradrypetes), Petalostigma, Phyllanthus, Piranhea, Protomegabaria, Putranjiva, (Sauropus), Savia, Securinega, Uapaca.

Crotonoideae

Acalypha, (Acidocroton), Actinostemon, Adelia, (Adenocline), (Adenopeltis), Agrostistachys, Alchornea, Alchorneopsis, Aleurites, Anthostema, Aparisthmium, Baloghia, Blachia, Blumeodendron, Caryodendron, Chaetocarpus, Claoxylon, Cleidion, Cleistanthus, (Cnesmone), Coccoceras, Codiaeum, Coelodepas, (Colliguaja), (Conceveiba), Conceveibastrum, Croton, Cunuria, Dimorphocalyx, Discoglypremna, Elateriospermum, Endospermum, Euphorbia, Excoecaria, Fontainea, (Galearia), Garcia, Gavarretia, Gelonium, Givotia, Grossera, Gymnanthes, Hevea, Hippomane, Homalanthus, Homonoia, Hura, Jatropha, Joannesia, Lasiocroton, Leucocroton, Mabea, Macaranga, Mallotus, Manihot, Maprounea, Mareya, Melanolepis, (Mercurialis), Microdesmis, Nealchornea, Necepsia, Neoboutonia, Neoscortechinia, Omphalea, Ostodes, (Pachystroma), Pausandra, (Pedilanthus), Pera, Pimeleodendron, Pogonophora, Pseudagrostistachys, Pycnocoma, Ricinodendron, Ricinus, Sagotia, Sapium, Savia, Sebastiania, Senefeldera, (Stillingia), Sumbavia, Tetrorchidium, Tragia, Trewia, Trigonopleura, Trigonostemon, Wetria.

Uncertae Sedis (described under Crotonoideae)

(Celaenodendron), Ptychopyxis.

Literature

(i) *On General Anatomy*

Alexandrov and Alexandrova **17**, Ashplant **46**, Bryce **301**, Bugnon **306**, Cameron **330**, Cummings **513**, Dehay **557**, Denis **565**, Dommel **596**, Frey-Wyssling **711**, Gandrup **739**, **740**, Griebel **820**, Gruning **829**, Gunnery **850**, Holm **994**, **1051**, Iwanowa-Paroiskaja **1128**, Jablonskzy **1129**, Keuchenius **1235**, Kienholz **1236**, Léandri **1327**, Lourteig and O'Donnell **1395**, Milanez **1520**, Moyer **1567**, Parija and Misra **1653**, Pax **1662**, **1663**, **1664**, **1665**, **1666**, **1667**, **1668**, Pax and Hoffmann **1669**, **1670**, **1671**, **1672**, **1673**, Penfound **1685**, Perry **1699**, Popham **1734**, Quisumbing **1768**, Reed **1895**, Reiche **1910**, Reynolds **1930**, **1931**, Ritterhausen **1942**, Sabnis **1977**, Santos **1993**, Sarkany **1996**, Scott **2068**, **2071**, Sharples **2083**, Sharples and Gunnery **2084**, Stade **2179**, Starr **2188**, Trumke **2286**, Varossieau **2324**, Vischer **2336**, **2337**, White, Dyer, and Sloane **2419**, Yampolsky **2481**, Zemke **2505**.

(ii) *On Wood Structure*

Bailey **78**, Baker **104**, Becking *et al.* **164**, Beekman **167**, Benoist **170**, den Berger **179**, **182**, **183**, Besson **186**, Bobilioff **210**, Brown, F. B. H. **282**, Burgerstein **310**, **312**, Burtt Davy **315A**, Chalk *et al.* **364**, Chalk and Chattaway **358**, Cockrell **434**, Cooper and Record **461**, Coster **481**, Dadswell **525**, Dadswell and Record **533**, Desch **574**, Edmondson **623A**, Giordano **786**, Gonggrijp **794**, Heimsch **938**, Howard **1088**, Janssonius **1150**, **1151**, **1154**, Jolly **1188**, Jones **1191**, Kanehira **1206**, **1209**, Kribs **1283**, Lecomte **1334**, Link **1377**, Messeri **1493**, Metcalfe **1496**, Milanez **1520**, Panshin **1649**, Pearson and Brown **1679**, Petch **1701**, Pfeiffer, H. **1712**, Pfeiffer, J. Ph. **1713**, Record **1783**, **1801**, **1823**, **1843**, **1851**, **1854**, Record and Hess **1886**, Record and Mell **1894**, Scott **2075**, Stone **2202**, **2206**, **2207**, Varossieau **2324**, Webber **2377**, Williams **2427**, **2430**, Yamabayashi **2478**.

244. BUXACEAE

(FIG. 296 on p. 1238; FIG. 297 on p. 1240)

SUMMARY

(i) GENERAL

A widespread, but somewhat scattered, family which occurs in temperate and sub-tropical regions excluding South America. It consists of small trees and shrubs with shining, coriaceous leaves. The leaf is generally dorsiventral, although the abaxial part of the **mesophyll** is very dense in some species. The rather infrequent, thick-walled, simple **hairs** consist of 1 to several cells. **Stomata,** confined to the lower surface, are surrounded by a fairly well-defined rosette of subsidiary cells. The **petiole** is usually supplied by 1 large median and 2 smaller lateral vascular strands, but the lateral bundles in certain species of *Buxus* are replaced by strands consisting only of fibres. In the young stem of *Buxus*, but not of the other genera, a single **cortical bundle** is commonly present in each of the 4 angles. **Crystals** are secreted in the form of solitary and clustered types, or as rather coarse sand with a corroded appearance.

(ii) WOOD (not including *Simmondsia*)

Vessels very to extremely small, exclusively solitary, very numerous, usually with exclusively scalariform perforation plates, intervascular pitting usually very small, opposite to transitional, pits to parenchyma similar, members typically of medium length, very long in *Styloceras*. **Parenchyma** apotracheal, diffuse, strands usually of 4 cells. **Rays** up to 2–4 cells wide, with numerous uniseriates, usually markedly heterogeneous. **Fibres** with small to large bordered pits, usually moderately to very short, but of medium length to moderately long in *Styloceras*.

LEAF

Dorsiventral in *Buxus*, *Pachysandra*, *Sarcococca*, *Styloceras*. **Hairs** in *Buxus* and *Pachysandra* simple, thick-walled, unicellular, or with several transverse septa. **Stomata** confined to the lower surface, surrounded by rosettes of more or less clearly defined subsidiary cells. Guard cells strongly crested in *Buxus sempervirens* Linn. Abaxial half of the **mesophyll** very dense, except in species of *Buxus* belonging to the section *Eubuxus*, where the spongy tissue is very lacunar. **Petiole** (Fig. 296 A–B), in transverse sections through the distal end, exhibiting a large median and 2 smaller, lateral vascular bundles in American and African species of *Buxus* as well as in *Pachysandra* (Fig. 296 A), *Sarcococca*, and *Styloceras*; only a single median vascular bundle, accompanied at either end by a lateral strand of fibres, present in European and Asiatic species of *Buxus* (Fig. 296 B) belonging to the section *Eubuxus*. **Crystals** of calcium oxalate secreted in the mesophyll in the form of clusters, or as solitary types accompanying the vascular bundles of the veins. Relatively coarse crystal-sand with a corroded appearance also present in special cells resembling white dots along the median vein on the lower surface of the leaf of *Buxus sempervirens*. **Secretory cells** (see also under 'Axis') prominent in the palisade tissue of *B. sempervirens* on account of their bright, strongly refractive contents in the living leaf. These contents become brown on treatment with iodine.

AXIS

STEM (Fig. 296 D–E)

Epidermis papillose and strongly cutinized in *Buxus balearica* Willd. and *B. sempervirens* Linn.; outer wall strongly cutinized, but not papillose, in *Sarcococca hookeriana* var. *humilis* Rehd. et Wils. and *S. ruscifolia* Stapf. **Cork** sub-epidermal in *Buxus*. Primary **cortex** wider and composed of cells with thinner walls in *Pachysandra terminalis* Sieb. et Zucc. than in the species of *Buxus* and *Sarcococca* examined at Kew; often chlorenchymatous, e.g. in *Buxus* (Fig. 296 E). Primary cortex, and sometimes the pith phloem and pericycle, said by Solereder to include groups of sclerenchymatous elements, the latter sometimes containing solitary crystals in *Buxus* (especially African species), *Notobuxus* and *Pachysandra procumbens* Michx. **Pericycle** including a few inconspicuous strands of fibres in certain, but not all, species of *Buxus* and *Sarcococca*; occasional, solitary, thick-walled fibres noted in *Pachysandra terminalis*; fibre strands small and more numerous in *Sarcococca hookeriana* var. *humilis* and *S. ruscifolia* than in *Buxus* and *Pachysandra*. Occasional pericyclic fibres also recorded in *Styloceras*. **Xylem** in the form of a continuous cylinder traversed by narrow rays; occupying a smaller proportion of the stem in *Pachysandra terminalis* than in the other genera examined at Kew. Vessels with scalariform perforation plates. A **cortical vascular bundle** (Fig. 296 E) noted at Kew in each of the 4 angles of the stem in *Buxus balearica* and *B. sempervirens*, each bundle being accompanied by 1, or sometimes 2, strands of fibres. Similar cortical bundles stated by Solereder to occur in all species of *Buxus* from the Old World and in *Notobuxus natalensis* Oliv., but believed to be absent from American species of *Buxus*. No cortical bundles seen in *Pachysandra* and *Sarcococca*.

Pith composed of somewhat prosenchymatous, thick-walled, pitted cells, the latter appearing circular in transverse sections, in *Buxus balearica* and *B. sempervirens*; consisting of moderately thick-walled cells in *Sarcococca hookeriana* var. *humilis*; somewhat heterogeneous and becoming hollow in *S. ruscifolia*; thin-walled in *Pachysandra terminalis*. A few cluster **crystals** noted in the cortex of *Buxus balearica*; numerous solitary crystals in the phloem, a few in the pith, and others in cells around the fibre strands associated with the cortical bundles observed in the same species. Crystals of the same types, and similarly distributed but less numerous, in *B. sempervirens*. Solitary crystals in the cortex, and crystal-sand in the cortex and pith, recorded by Solereder in *Pachysandra*, but no crystals observed at Kew in the few species of *Pachysandra* and *Sarcococca* examined. **Secretory cells**, arranged in longitudinal rows, recorded in *Pachysandra procumbens*.

WOOD (Fig. 297 C–G)

Vessels typically very small (mean tangential diameter 25–50 μ) to extremely small (less than 25 μ), but rather larger in *Styloceras*; exclusively solitary, apart from apparent tangential pairs due to overlapping ends; typically about 200 per sq. mm. or more, except in *Styloceras* (about 30 per sq. mm.). Perforation plates exclusively scalariform except for rare simple perforations reported (2261) in *Buxus*; the plates usually with fewer than 20 bars, but commonly with 30 or more in *Styloceras* and, according to Solereder, in *Pachysandra*, *Sarcococca*, and *Buxus subcolumnaris* Müll. Arg. of the section *Tricera*; the bars not exceeding 15 in species of *Buxus* belonging to the section *Eubuxus*; occasionally foraminate, e.g. in *Notobuxus acuminata* Hutch. Intervascular pitting rare, typically opposite and small to minute, but rather larger and tending to be scalariform in *Styloceras*; pits to wood and ray parenchyma similar to the intervascular pitting. Mean member length usually about 0·5–0·6 mm., but 1·0 mm. in *Styloceras*. **Parenchyma** apotracheal, typically as isolated cells scattered among the fibres (Fig. 297 G), but tending to form short lines in *Styloceras*; tending to be associated with the vessels in some specimens of *Buxus*, particularly of *B. sempervirens* Linn. (Fig. 297 F). Strands of 2–8, mostly 4, cells. **Rays** typically 2 cells wide, but sometimes up to 4 cells wide in *Styloceras*; typically low, but often more than 1 mm. high in *Styloceras*; uniseriates numerous, usually composed of square to upright cells only, but of mixed procumbent and upright cells in *Buxus macowani* Oliv.; 12–19 rays per mm.; markedly heterogeneous (Kribs's Type I) and commonly with more than 4 marginal rows of upright cells in *Styloceras* (Fig. 297 C), less pronouncedly heterogeneous (Kribs's Type II A), with 1–4 marginal rows of upright cells, in most of the other genera and species, but homogeneous (Kribs's Type I) in *Buxus macowani* (Fig. 297 D). **Fibres** with bordered pits, the borders small and sometimes rather indistinct in *Buxus* and *Notobuxus*, but large and distinct in *Styloceras*; the pits equally numerous on both radial and tangential walls. Walls thick. Solereder refers to spiral thickening in *Pachysandra*. Mean length usually 0·6–0·9 mm., but

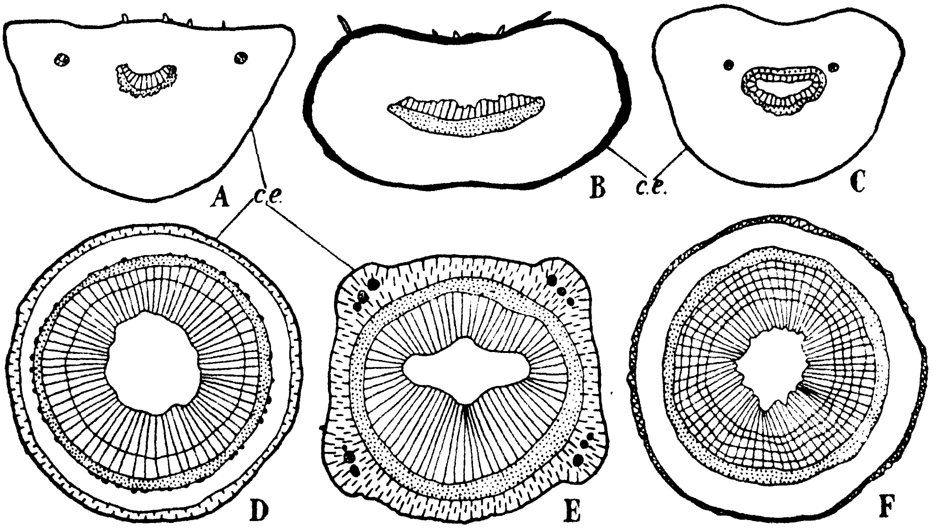


FIG. 296. *BUXACEAE*, A–B and D–E; *DAPHNIPHYLLACEAE*, C and F

A, *Pachysandra terminalis* S. et Z. Petiole × 15. B, *Buxus balearica* Lam. Petiole × 22. C, *Daphniphyllum macropodum* Miq. Petiole × 12. D, *Sarcococca humilis* Stapf. Stem × 12. E, *Buxus balearica* Lam. Stem × 13. F, *Daphniphyllum humile* Maxim. Stem × 9.

c.e. Cutinized epidermis.

about 1·6 in *Styloceras*. The development of the **growth rings** in *Buxus sempervirens* Linn. introduced into Java has been investigated by Coster (481).

SIMMONDSIA

As the genus *Simmondsia*, which is represented by the single species *S. californica* Nutt., differs in many important respects from the other genera included in the Buxaceae, it is here described separately, the description of the leaf and stem being based mainly on information recorded by Solereder.

LEAF

Hairs relatively long, uniseriate, consisting of apparently articulated cells with thick walls, but 1 or 2 of the terminal cells with thinner walls described by Solereder as possibly glandular. Cells of the **epidermis** small and polygonal as seen in surface view; resembling palisade cells in transverse sections, but with conical tapering of the lumen towards the adaxial side, and provided with thick outer walls. **Stomata** equally numerous on both surfaces; ranunculaceous; somewhat depressed. **Mesophyll** consisting wholly of palisade cells. Vascular bundles of the **veins** accompanied by sclerenchyma. **Petiole** containing an arc-shaped vascular strand, which becomes closed to form a ring. **Secretory elements.** Some of the cells of the palisade parenchyma in dried material contain yellowish tanniniferous material, turning brown when treated with eau de Javelle. Clustered **crystals** abundant at the periphery of the leaf, and solitary types, some resembling styloids, in the central tissues.

AXIS

STEM

Chiefly remarkable for **anomalous growth in thickness** by the development of successive, concentric rings of xylem and phloem, originating in the pericycle and becoming separated from one another by narrow circles of lignified parenchyma. Anomalous structure also reported to occur in the root. The phloem in each consecutive ring consists of isolated strands, with parenchymatous ground-tissue separating the groups in each vascular ring. Other features include **cork** originating in the pericycle; strands of fibres in the **pericycle.**

WOOD (Fig. 297 H)

The main points of difference from the preceding description of the family are as follows. **Vessels** with spiral thickening, simple perforations, alternate intervascular pitting, and a mean member length of about 0·2 mm. **Parenchyma** very rare, except for the bands of conjunctive tissue associated with the anomalous structure. **Fibres** with large, distinctly bordered pits and a mean length of about 0·4 mm. **Included (interxylary) phloem** of the 'concentric' type present, with layers of xylem separated by phloem and conjunctive parenchyma; interfascicular rays usually rather rare, but common locally; phloem strands round to oval in cross-section.

TAXONOMIC NOTES

Certain features, such as solitary vessels, diffuse parenchyma, and fibres with bordered pits, appear to be constant throughout the family. Neverthe-

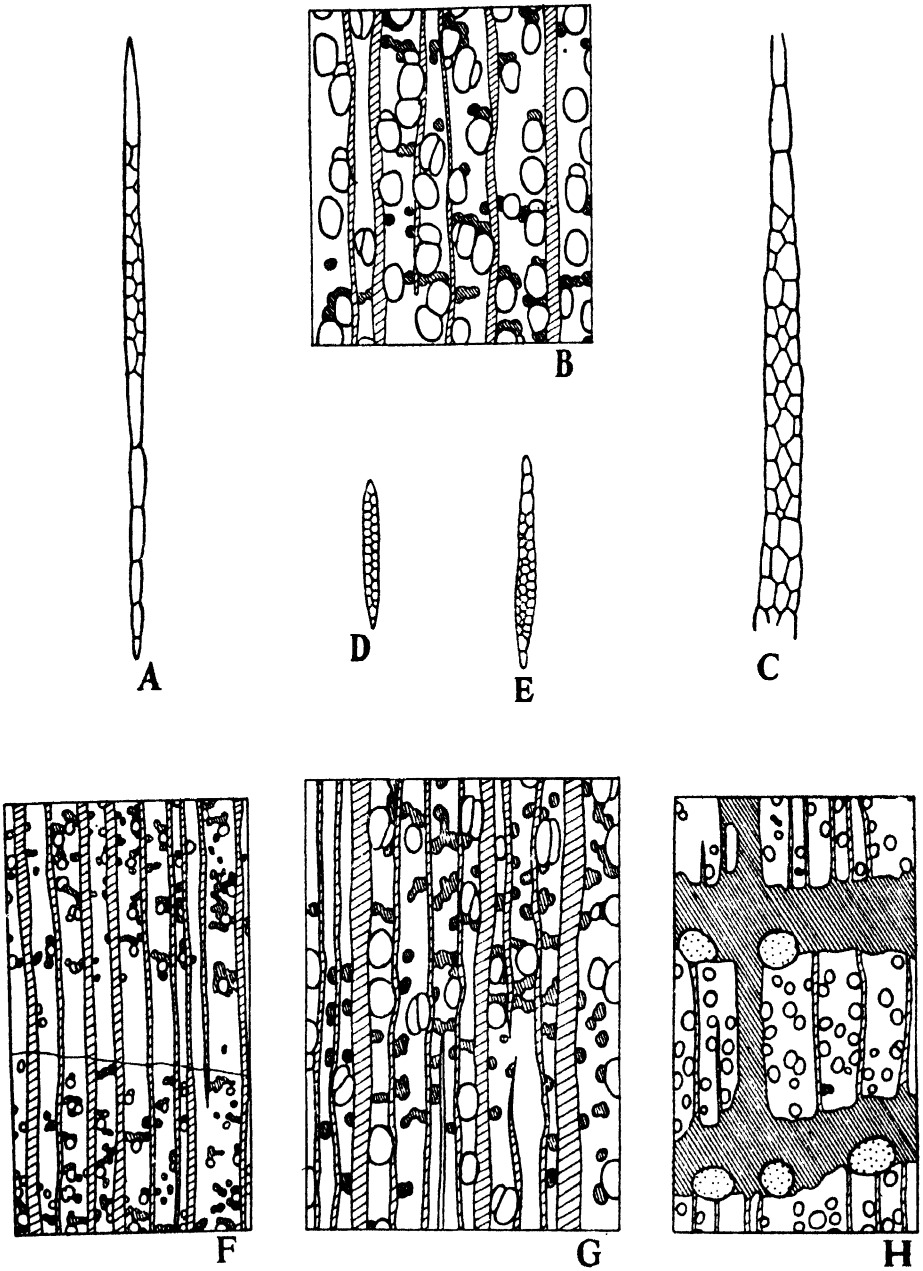


FIG. 297. *DAPHNIPHYLLACEAE*, A–B; *BUXACEAE*, C–H

A, ***Daphniphyllum laurifolium*** Hook. f. B, ***D. laurifolium*** Hook. f. C, ***Styloceras laurifolium*** H. B. et K. D, ***Buxus macowani*** Oliver. E, ***B. sempervirens*** Linn. F, ***B. sempervirens*** Linn. G, ***Styloceras laurifolium*** H. B. et K. H, ***Simmondsia californica*** Nutt.

less, ***Buxus***, ***Simmondsia***, and ***Styloceras*** differ very markedly in their wood anatomy—more so than is usual among genera of one family. Such differences, however, might well be attributable to different degrees of specialization. ***Styloceras***, with its long vessel members, is clearly an unspecialized type with all its characters in harmony. *Simmondsia* is almost equally clearly a moderately highly specialized type, quite apart from its anomalous structure, with short vessel members (0·2 mm.), simple perforations, and alternate intervascular pitting, only the large bordered pits in the fibres appearing slightly out of character. *Buxus* is intermediate between these 2 genera, but is rather difficult to place on account of the length of its vessel members (0·5–0·6 mm.) being indicative of a distinctly more specialized type of structure than is suggested, for example, by its exclusively scalariform perforation plates and opposite intervascular pitting.

There seems to be some anatomical support (1884) for the distinctions between the different sections of *Buxus*.

ECONOMIC USES

True Boxwood, *Buxus sempervirens* Linn., is outstanding for its fineness of grain, density, and the smoothness with which it can be cut in any plane, and for special purposes, such as wood-engraving, it is unrivalled. It was at one time widely used for shuttles in the textile industries, but has been replaced by various substitutes. Some of the other species, e.g. *Buxus macowani* Oliv. from South Africa, produce very similar timber.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Buxus,* Notobuxus, Pachysandra,* Sarcococca,* Simmondsia, Styloceras.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Buxus, Notobuxus, (Pachysandra), (Sarcococca), Simmondsia, Styloceras.

LITERATURE

On Wood Structure

Bienfait and Pfeiffer **197**, Chalk and Chattaway **362**, Chalk and Rendle **365**, Chowdhury **411**, Coster **481**, Greguss **2522**, Howard **1088**, Kanehira **1206**, **1209**, Pfeiffer, H. **1712**, Record **1843**, **1851**, **1884**, Record and Hess **1886**, Scott **2075**, Stone **2203**, Tippo **2261**, Yamabayashi **2478**.

245. DAPHNIPHYLLACEAE

(FIG. 296 on p. 1238; FIG. 297 on p. 1240)

SUMMARY

A small family, ranging chiefly from the Malayan region to China and Japan, but with 1 species occurring on the Malabar coast. It consists of shrubs and small trees comprising the single genus *Daphniphyllum*. Very little information is available concerning the general anatomy, apart from that recorded by Rosenthal (1951, 1952). The wood is characterized by the following features. **Vessels** small, solitary and numerous, perforation plates scalariform, intervascular pitting scalariform to opposite, but rare, members moderately to very long. **Parenchyma** diffuse. **Rays** up to 2 cells wide, markedly heterogeneous. **Fibres** with distinctly bordered pits. Moderately to very long.

LEAF

Dorsiventral. **Epidermis,** especially on the upper surface, strongly cutinized; papillose on the lower surface in some species. **Stomata** confined to the lower surface; rubiaceous. Stone cells present in the ground-tissue of the petiole and at the leaf margin. Vascular bundles of the **veins** accompanied, above and below, by strands of fibres. **Petiole** (Fig. 296 C) supplied with a solitary cylindrical vascular strand. Idioblasts containing cluster **crystals** abundant. **Secretory elements** absent, according to Rosenthal, but cells with darkly staining, possibly tanniniferous, contents seen at Kew in the petiolar ground-tissue.

AXIS

STEM (Fig. 296 F)

Epidermis composed of small, thick-walled cells. Lenticels numerous. **Cork** sub-epidermal. Xylem in the form of a continuous cylinder traversed by rays 1–3 cells wide. Vessels with scalariform perforation plates. **Pith** septate; consisting of isodiametric to tubular cells, provided with bordered pits. Idioblasts containing cluster **crystals** abundant. **Secretory elements** absent according to Rosenthal, but some elongated cells with gum-like contents noted in the cortex of material examined at Kew.

WOOD (Fig. 297 A–B)

Vessels very to moderately small (30–60 μ mean tangential diameter), exclusively solitary apart from pairs due to overlapping ends; 70–220 per sq. mm. Perforation plates scalariform, with more than 20 fine bars. Intervascular pitting rare, opposite to scalariform; pits to ray and wood parenchyma similar, sometimes unilaterally compound. Tyloses reported by Janssonius (1154). Vessel member length 1·0–1·64 mm. **Parenchyma** scattered among the fibres and often in contact with the numerous vessels; probably apotracheal. Strands most commonly of 8, very high, cells. **Rays** up to 2 cells wide; seldom more than 1 mm. high; with numerous uniseriates composed of upright cells; about 14 rays per sq. mm.; markedly heterogeneous (Kribs's Types I and II A), with several rows of square or upright cells. **Fibres** with distinctly bordered pits, equally numerous on both radial and tangential walls; walls moderately thin to moderately thick. Occasional crystalliferous fibres recorded by Janssonius (1154). Mean length 1·4–2·3 mm.

TAXONOMIC NOTES

The wood anatomy is distinct from that of any of the genera of the Euphorbiaceae. Janssonius (1151, 1154) has shown that these differences alone are sufficient to cause one to doubt whether the genus should properly be included in that family. He considers its affinities to be rather with a large group of families that includes, for example, the Theaceae (sensu lato) and Hamamelidaceae.

GENUS DESCRIBED

Daphniphyllum.*

* Represented in the Kew slide collection.

LITERATURE

(i) *On General Anatomy*
Rosenthal **1951, 1952.**

(ii) *On Wood Structure*
Janssonius **1151, 1154,** Kanehira **1206,** Record **1851,** Tang **2231,** Yamabayashi **2478.**

246. BALANOPSIDACEAE

SUMMARY

A small family of trees and shrubs belonging to the single genus *Balanops* from New Caledonia. Guillaumin (842), who reinvestigated the anatomy of the family, failed to discover any important new features beside those previously described by Solereder.

LEAF

Dorsiventral. **Epidermis** composed of cells with polygonal outline as seen in surface view, and very thick outer walls. A single layer of **hypoderm** present beneath the upper epidermis in *B. balansae* Baill. and *B. microstachya* Baill. **Stomata** confined to the lower surface; ranunculaceous; guard cells provided with strongly developed cuticular ridges. Vascular bundles of the **veins** embedded in the mesophyll and surrounded by a ring of sclerenchyma. Enlarged terminal tracheids sometimes present at the ends of the veins. Three arc-shaped vascular bundles enter the base of the **petiole** of *B. vieillardi* Baill. but become closed to form 3 rings higher up, finally opening out again before entering the lamina. Clustered **crystals** fairly abundant in the mesophyll of certain species.

AXIS

YOUNG STEM

Cork arising in the sub-epidermis of *B. microstachya* Baill., consisting of narrow tabular cells with rather thick walls. A ring of stone cells present on the inside of the phellogen in the same species, and numerous sclerosed cells in the cortical parenchyma of *B. balansae* Baill. **Pericycle** including a composite continuous ring of sclerenchyma. **Xylem** consisting of a continuous cylinder traversed by narrow rays; including mostly isolated vessels up to 21 μ in diameter, with simple, slit-shaped pits to the medullary ray cells, and provided with scalariform perforation plates with numerous bars; fibres with thick walls and narrow lumina, those of *B. microstachya* with simple, and those of *B. balansae* with bordered, pits; very narrow medullary rays composed of upright cells.

GENUS DESCRIBED

Balanops.

LITERATURE

On General Anatomy
Guillaumin **842.**

247. URTICACEAE

(FIG. 298 on p. 1244; FIG. 299 on p. 1248; FIG. 300 on p. 1250)

SUMMARY

(i) GENERAL

Many members of this widely distributed family are herbs and shrubs, but some are trees in which the xylem is very soft, owing to its being composed largely of unlignified parenchyma. The **stinging hairs,** so familiar in *Urtica dioica* Linn., also occur in some of the other genera, but are by no means universally present throughout the family. The heads of these hairs are easily detached, liberating an irritating fluid, of uncertain chemical composition.

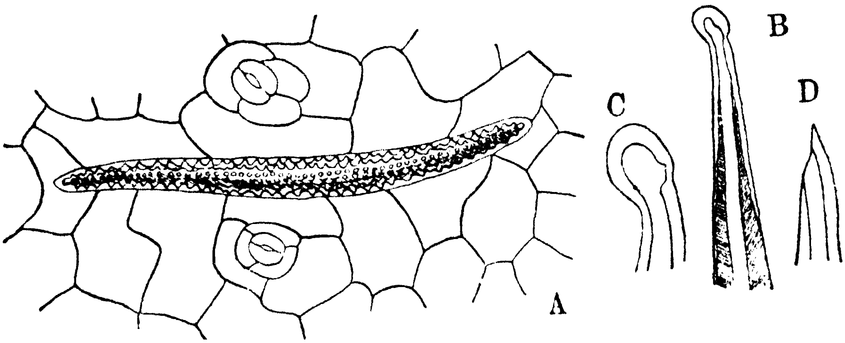


FIG. 298. *URTICACEAE*

A, Upper epidermis of the leaf of *Pilea serpyllifolia* Wedd. with a cystolith. B–D, Stinging hair of *Urtica dioica* L.: B, upper portion of the same; the shaded part of the wall is calcified, the unshaded part silicified; C, Tip of the stinging hair before, and D after, the head has been broken off.—A by Solereder, B after Kohl, C–D after Haberlandt.

Glandular and simple trichomes are also present. **Cystoliths,** usually independent of the hairs, are abundant, especially in the integumentary tissues. They are somewhat variable in size and shape, the different types being useful to some extent for taxonomic purposes. The cell walls, especially of the hairs and epidermal cells, are also silicified in some instances. The **stomata** are somewhat variable in type and distribution. **Hydathodes** are sometimes present as well. **Secretory elements,** in the form of mucilage cells, and less frequent cavities, also occur, the former having been observed in the parenchymatous tissues of the axis in numerous genera. Laticiferous canals have been recorded in *Laportea* and *Urera* and secretory canals lined with epithelium in *Pilea*. **Crystals** are mostly clustered, but raphides have been recorded in *Laportea*. Groups of unlignified fibres in the pericycle provide a very striking feature of the axis. In some instances they are of technical importance.

(ii) WOOD

Vessels medium-sized to large, usually few, perforations simple, intervascular pitting alternate and large, pits to parenchyma simple and typically elongated, members usually short but sometimes up to moderately long. **Parenchyma** commonly of 2 types: (*a*) normally lignified cells about the vessels, and (*b*) unlignified arcs and bands, often, when partially disintegrated, resembling included phloem; storied structure and fusiform cells typical of some genera. **Rays** up to 5–10 cells wide and high, typically with few or no uniseriates, few and heterogeneous or more commonly composed entirely of square and upright cells. **Fibres** usually with simple pits, commonly septate, of medium length to moderately short.

LEAF

Generally dorsiventral, the palisade tissue occupying half the thickness of the lamina according to Mohler (1544). **Hairs** include glandular, non-glandular, and stinging types. (A) Non-glandular hairs mostly unicellular, sometimes bracket-shaped in *Boehmeria*, *Forskohlea* and *Parietaria*. Unicellular hairs sometimes hooked in *Boehmeria*. A white tomentum of woolly hairs recorded on the lower surface in *Boehmeria nivea* Gaud. by Mohler (1544). Non-glandular hairs absent from certain species of *Pellionia* and *Pilea*. (B) Glandular hairs each having a unicellular stalk and a head of a few (frequently 4) cells present in *Boehmeria*, *Laportea*, *Urtica*. Peltate glands recorded in *Pellionia*. Pearl glands, each composed of an epidermal envelope of small tabular cells enclosing a few large cells filled with protoplasm and fatty material, present in certain species of *Urtica*. (C) Stinging hairs (Fig. 298 B–D) known to occur in species of *Fleurya*, *Girardinia*, *Hesperocnide*, *Laportea*, *Urera*, *Urtica*. Those of *Laportea* and *Urtica* long, conical, and silicified, especially towards the apex, the contents of the hairs being readily emitted following the loss of the obliquely inserted, easily detachable head. For further particulars concerning the stinging mechanism see Nestler's (1586) article. The chemical nature of the irritant material in the stinging hairs has not been definitely established, but it is not formic as was at one time supposed. Irritant said by Flury (688) to be 'a non-nitrogenous, unsaturated substance of an acid nature resembling resinic acid'. A few more particulars concerning hairs recorded below under 'Cystoliths'.

Stomata confined to the lower surface in species of *Elatostema*, *Helxine*, *Laportea*, *Parietaria*, *Pellionia*, *Pilea*, and *Urtica* examined by Mohler (1544); occurring sporadically on the upper surface in *Pilea spruceana* Wedd., and, according to Solereder, on the thick, fleshy leaves of *P. serpyllifolia* Wedd.; ranunculaceous in *Boehmeria* (Holm 1014), *Pilea* (pro parte), but cruciferous in other species of *Boehmeria* and *Pilea* (Fig. 298 A) as well as in species of *Elatostema*, *Laportea*, *Pellionia*. **Hydathodes** on the upper surface recorded by Mohler (1544) in *Boehmeria nivea* Gaud., *Elatostema sessile* Forst., *Helxine soleiroli* Req., and by Solereder, besides some of the above genera, in a few species of *Urtica*. Hydathodes present on the lower surface according to the same authors in a few species of *Pellionia* and *Pilea*, those in *P. serpyllifolia* being in the form of pores at the terminations of veins. **Epidermis** frequently consisting of large, aqueous cells (Mohler 1544). **Silicification** and **calcification** of the cell wall, especially of the epidermis and hairs, sometimes occurs, but the presence of cystoliths independently of the hairs is far more common.

Cystoliths (Fig. 298 A). The following facts concerning cystoliths have been recorded by Solereder. Cystoliths usually spherical, ellipsoidal, or fusiform, more rarely exhibiting stellate branching; appearing in the dried leaf as

dots, tubular or linear markings, or as star-shaped bodies. Cystoliths appearing as dots reported to occur in *Boehmeria*, *Chamabainia*, *Cypholophus*, *Distemon*, *Droguetia*, *Gesnouinia*, *Girardinia*, *Hemistylus*, *Laportea* (cystoliths small), *Leucosyke*, *Maoutia*, *Memorialis*, *Neraudia*, *Obetia*, *Parietaria*, *Phenax*, *Pipturus*, *Pouzolzia*, *Sarcochlamys*, *Touchardia*. Cystoliths appearing as linear or fusiform markings, said to be confined to *Achudemia*, *Elatostema*, *Fleurya*, *Helxine*, *Lecanthus*, *Myriocarpa* (cystoliths radiating from the bases of the hairs), *Nanocnide*, *Pellionia*, *Procris* (very small). Cystoliths of both of the above types recorded in *Australina*, *Gyrotaenia*, *Hesperocnide*, *Pilea*, *Poikiloespermum*, *Urera*, *Urtica*. Cystoliths with stellate branching recorded only in species of *Pilea*.

Bigalke's (198) more recent work on cystoliths, crystals, and hairs as revealed in **spodograms** (leaves which have been slowly incinerated before mounting for microscopical examination) of numerous species of Urticaceae, may now be considered. Cystoliths very varied in form, ranging from narrow, elongated, straight or curved types to round forms, intermediate kinds being rod-shaped, elliptical or angular. Surface of the cystoliths frequently covered with small, wart-like protuberances. One or more types of cystolith occur in a single spodogram according to the species. Cystoliths exhibit a wide range of size, large ones like those of *Elatostema glomeratum* C. B. Rob. being up to 558 μ long and 54 μ wide. Cystoliths usually evenly distributed over the whole surface of the leaf, but varying in frequency in different species; confined to the region of the veins in a few species. Cells surrounding the cystoliths, especially when the latter are situated in hairs or papillae, often differentiated from their neighbours in size or by having calcified or silicified walls. A definite circle of cells with thicker walls recorded around the bases of cystolith-bearing hairs in a few instances. All cystoliths calcified, at least to a certain extent; strongly silicified in a few species of *Cypholophus*, *Elatostema*, *Leucosyke*, *Maoutia*, *Urtica*; weakly silicified in species of *Astrothalamus*, *Boehmeria*, *Boehmeriopsis*, *Hesperocnide*, *Parietaria*, *Villebrunia*. No genus wholly devoid of cystoliths, but these are absent from certain species; especially numerous at the leaf margin. Subsidiary cystoliths, although common in *Cannabis* (Family Cannabinaceae), observed amongst the Urticaceae only in *Maoutia setosa* Wedd.

According to Bigalke the characters of the spodograms enable the family to be divided into groups, and these correspond to the tribes that are generally recognized by taxonomists, and which are based on exomorphic features. This claim appears to be approximately correct if allowance is made for certain exceptions. Bigalke's spodogram characters for the tribes are as follows.

(i) UREREAE. Cystoliths very variable, ranging from round to elongated; mostly round in *Girardinia*, *Laportea*, *Obetia*, *Sceptrocnide*, *Urtica*, and elongated in *Fleurya*, *Hesperocnide*, *Nanocnide*, both types being equally numerous in *Urera*. Elongated cystoliths of *Gyrotainia* slightly or conspicuously curved according to the species. Cluster crystals generally present, but absent from *Obetia* and some species of *Urera* and *Urtica*. Raphides present in certain species of *Laportea*. Hairs shaped like goats' horns absent from the whole tribe.

(ii) PROCRIDEAE. Narrow, elongated cystoliths present throughout the tribe. Spodograms of *Achudemia* and *Pilea* obscure; cystoliths with small, flat protuberances present, but not easily seen; infrequent cluster crystals observed only in 1 species of *Pilea*. Spodograms of *Elatostema*, *Elatostemoides*, and *Pellionia* much less obscure; cystoliths with large protuberances; cluster-crystals numerous, large, and conspicuous. Cystoliths very numerous and curved in *Sarcopilea* (cf. *Touchardia* in the Boehmerieae). Hairs very infrequent; trichomes resembling goats' horns absent.

(iii) BOEHMERIEAE. Cystoliths of various sizes and shapes; hairs also varied in form; cluster crystals differing in frequency and distribution. Genera falling into 4 distinct groups: (*a*) *Myriocarpa*, *Touchardia*. Cystoliths elongated; those of *Touchardia* curved (cf. *Sarcopilea* in the Procrideae); stellate in *Myriocarpa*. (*b*) *Leucosyke*, *Maoutia*. Spodograms confused, exhibiting small, circular cystoliths, situated in hairs or papillae with sheathing cells. (*c*) *Boehmeriopsis*. Cystoliths mostly associated with hairs; infrequent, very variable in size, provided with flat, inconspicuous protuberances. (*d*) Remaining genera in this tribe provided with round cystoliths.

(iv) PARIETARIEAE. All genera except *Helxine* exhibiting round cystoliths with conspicuous protuberances. Cluster crystals present in all genera; numerous in *Gesnerainia*, *Rousselia*, and a cultivated specimen of *Helxine soleiroli* Req.; isolated, or visible only in transverse sections in the remaining genera. Spodograms of *Helxine* filled with mineral fragments, and exhibiting cystoliths of very irregular shape, some being elongated with rounded ends.

(v) FORSKOHLEAE. Half of the species of *Australina* provided with narrow, round or elliptical cystoliths with flat, very inconspicuous protuberances. Remaining species of *Australina* and other genera in this tribe characterized by round cystoliths with wide protuberances. Cluster crystals, hairs shaped like goats' horns, and long, pointed trichomes present in all genera.

Satake (1997) has also studied spodograms of some Japanese Urticaceae. His conclusions are similar to those of Bigalke, but as there are minor differences between the accounts given by the 2 authors, the following facts from Satake's paper are here included. Cystoliths oblong elongated in *Nanocnide* (lying parallel to the leaf surface); ovate or irregularly elliptical in *Urtica*; fusiform in *Elatostema*, *Pellionia*, *Pilea* (lying parallel to the leaf surface in the last genus); rounded and provided with a rough surface in species of *Boehmeria*, *Debregeasia*, *Memorialis*, *Parietaria* (surface nearly smooth), *Pipturus*, *Pouzolzia* (surface waved), *Sceptrocnide*, *Villebrunia* (cogwheel-shaped in the last 2 genera).

The mode of development of the cystoliths in *Boehmeria* has recently been discussed by Scott (2073).

Petiole (Fig. 299 A, C, D, E), in transverse sections through the distal end, exhibiting a deeply crescentic arc of widely spaced, collateral bundles in species of *Boehmeria*, *Debregeasia* (Fig. 299 D), *Laportea* (Fig. 299 C), and *Urtica* (Fig. 299 E), or a comparatively shallow arc of 3 bundles in the corresponding region of *Parietaria officinalis* Linn. (Fig. 299 A); additional medullary bundles present in *Laportea canadensis* Gaud. (Fig. 299 C).

Crystals of calcium oxalate (see also under 'Cystoliths') very common and mostly clustered; generally situated around the veins, but said by Mohler (1544) to be numerous in the mesophyll in species of *Elatostema* and *Pellionia*; raphides recorded by Bigalke (198) and Mohler (1544) in several species of

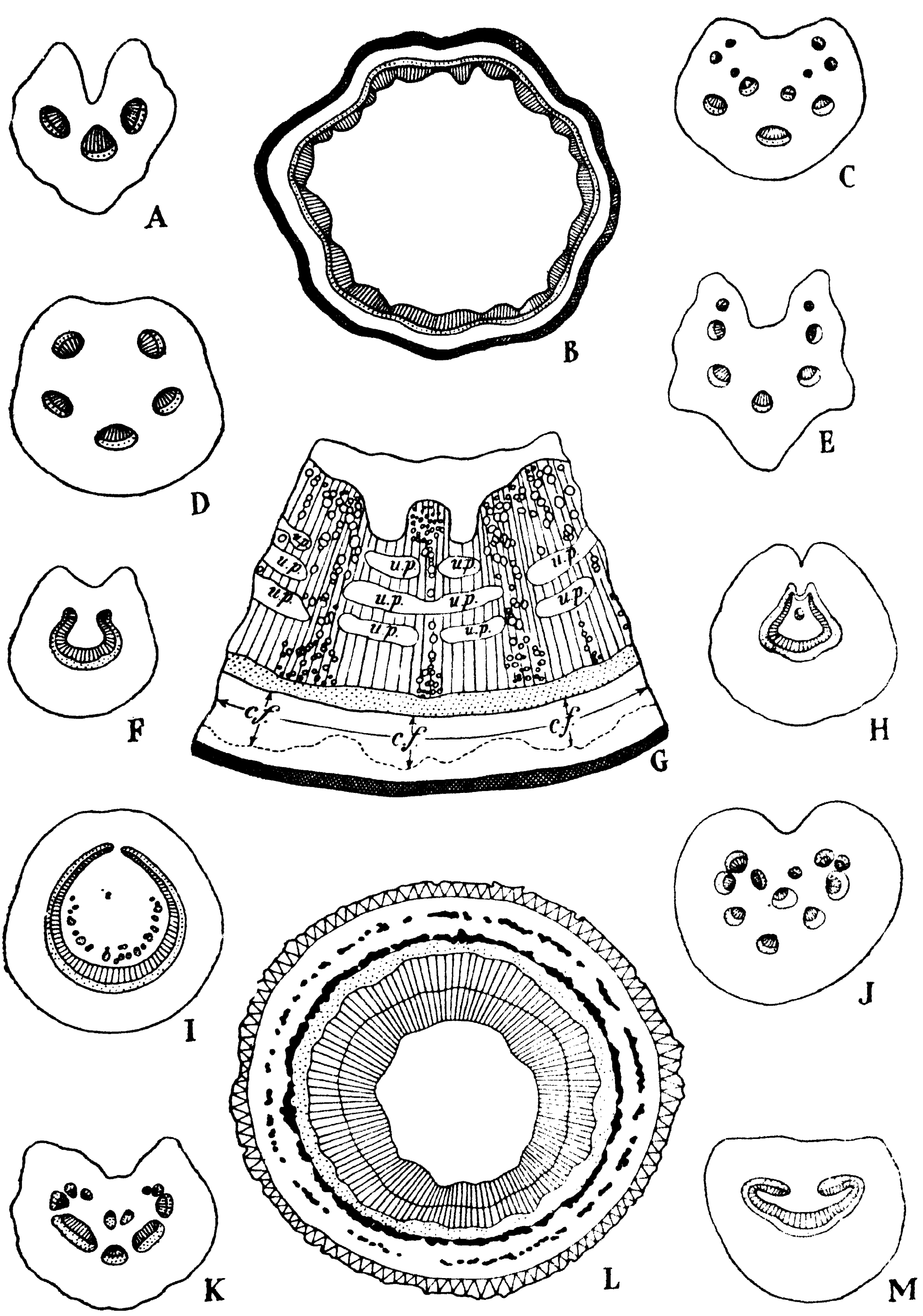


FIG. 299. *URTICACEAE*, A–E and G; *MORACEAE*, F and H–M

A, ***Parietaria officinalis*** Linn. Petiole ×47. B, ***Boehmeria nivea*** Gaudich. Stem ×8. (Unlignified pericyclic fibres as *c.f.* in Fig. G not shown.) C, ***Laportea canadensis*** Gaudich. Petiole ×14. D, ***Debregeasia velutina*** Gaudich. Petiole ×14. E, ***Urtica dioica*** Linn. Petiole ×19. F, ***Cudrania tricuspidata*** Bureau. Petiole ×19. G, ***Urtica dioica*** Linn. Stem ×19. H, ***Maclura pomifera*** Schneid. Petiole ×19. I, ***Ficus carica*** Linn. Petiole ×8. J, ***Brosimum alicastrum*** Sw. Petiole ×13. K, ***Morus alba*** Linn. Petiole ×19. L, ***M. nigra*** Linn. Stem ×19. M, ***Antiaris toxicaria*** Lesch. Petiole ×14.

c.f. Scattered cellulose fibres. ***u.p.*** Unlignified parenchyma.

Laportea, and a lack of crystals by Mohler in species of *Pilea* and *Helxine soleiroli* Req., and in *Maoutia* by Bigalke.

Secretory elements. Variously distributed mucilage cells occurring and frequently abundant in many genera. Mucilage cells isolated, arranged in axial rows or occasionally forming masses, the latter becoming converted lysigenously to mucilage cavities in *Myriocarpa*. Mucilage itself often deposited in strata. The following notes on the distribution of mucilage cells have been recorded by Guérin (833, 834, 836).

(i) UREREAE. Mucilage cells seen in *Girardinia* (most species), *Gyrotainia* (more numerous in leaf than stem), *Laportea* (distribution varying from one species to another), *Nanocnide* (in pith), *Urera* (in 7 species), *Urtica*. Mucilage cells absent from *Fleurya*, *Hesperocnide*, *Obetia*.

(ii) PROCRIDEAE. Mucilage cells seen in *Achudenia* (in the 1 species examined), *Elatostema* (in 20 species, but distribution variable), *Lecanthus* (in 1 species examined), *Pellionia* (in 8 species), *Procris* (in all species). No mucilage cells seen in the 15 species of *Pilea* examined.

(iii) BOEHMERIEAE. Mucilage cells seen in *Boehmeria* (6 species), *Debregeasia* (abundant in *D. wallichiana* Wedd.), *Memorialis* (in 1 species), *Pipturus* (in certain species), *Pouzolzia* (in several species). No mucilage cells seen in any of the available species of the following genera: *Chamabainia*, *Cypholophus*, *Distemon*, *Leucosyke*, *Maoutia*, *Neraudia*, *Phenax*, *Villebrunia*. Mucilage present in cavities, formed by the breakdown of groups of cells, in several species of *Myriocarpa*. See also Wille (2425).

(iv) PARIETARIEAE. Mucilage cells abundant in *Rousselia*; none seen in *Gesnouinia*, *Helxine*, *Parietaria*.

(v) FORSKOHLEAE. No mucilage cells seen in *Australina*, *Droguetia*, *Forskohlea*.

For laticiferous elements and other secretory canals see under 'Young Stem'.

AXIS

YOUNG STEM (Fig. 299 B, G)

Cork arising superficially in *Boehmeria*, *Debregeasia*, *Myriocarpa* (Wille 2425), *Pouzolzia*, *Urera*, but, according to Solereder, much deeper in the cortex in *Urtica dioica* Linn. **Cortex** well developed in species examined at Kew; stone cells noted in this tissue in *Urera*, but not in other genera. **Pericycle** including isolated strands of fibres (Fig. 299 G). Individual fibre cells in *Urtica dioica* sometimes 7 cm. or more long; wall composed of pure cellulose. Fibres of wide diameter seen in species of *Boehmeria*, *Laportea*, *Parietaria*, *Urtica*; usually thick-walled, but with relatively thin walls in species of *Debregeasia* and *Parietaria*; those of *Laportea* extending well into the cortex. Phloem well developed in the species examined at Kew; characterized by large sieve tubes with prominent sieve plates. **Xylem** in the form of a continuous cylinder traversed by narrow rays in all of the species examined at Kew. Broader rays recorded by Solereder in certain relatively woody species of *Laportea* and *Urera*. Weakly developed groups of xylem, situated in the 4 angles of the stem and separated by broad medullary rays, recorded in *Pilea* (Sayeedud-Din and Abdus Salam 2015) and narrower rays in *Pellionia* by the same authors. Vessels with simple perforations. Alternating

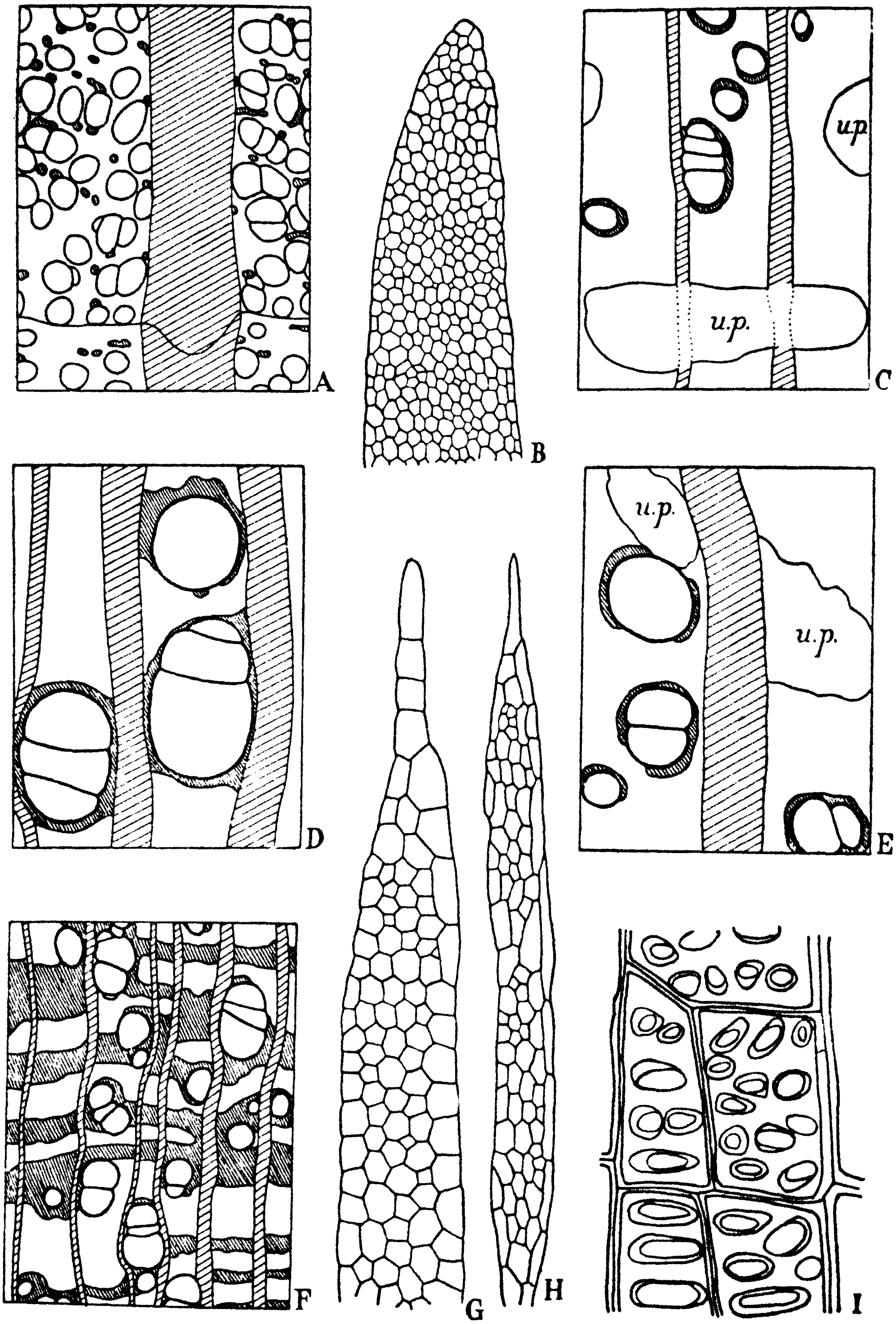


FIG. 300. *PLATANACEAE*, A–B, *URTICACEAE*, C–I

A, *Platanus orientalis* Linn. B, *P. orientalis* Linn. C, *Myriocarpa obovata* Donn. D, *Boehmeria rugulosa* Wedd. E, *Laportea luzonensis* Warb. F, *Obetia madagascariensis* (Juss. ex Poir.) Wedd. G, *Laportea gigas* Wedd. H, *Urera alata* (Swarz.) Griseb. I, *Laportea gigas* Wedd. Vessel-parenchyma pitting × 225.

u.p. Unlignified parenchyma.

zones of lignified and unlignified ground-tissue noted in the xylem of *Myriocarpa cordifolia* Liebm. and *Urtica dioica* (Fig. 299 G). More complex variations of this type of structure described in detail for *Urtica* by Kuster (1310) See also under 'Wood'.

Cystoliths, similar to those described under 'Leaf', also occur in the epidermis, cortex, phloem, and pith of the axis. **Crystals** mostly secreted as ordinary solitary or clustered types, but bundles of raphides and styloids present in *Laportea*. Clusters noted in the unlignified tissues in all of the species examined at Kew except *Pilea muscosa* Lindl., their distribution varying considerably in different species. **Secretory elements.** For mucilage cells see under 'Leaf'. Mucilage canals reported to occur in the cortex and pith of *Boehmeria*, *Laportea*, *Pipturus*. Laticiferous canals containing albuminoid bodies also recorded by Solereder, and, more recently, by Guérin (834, 836), at the periphery of the pith, in the inner portion of the primary cortex, in the secondary phloem, sometimes extending through the petiole into the veins of the leaf and also to the root in *Laportea* (6 species) and *Urera* (2 species). Secretory canals, distinct from laticiferous elements, and each lined with epithelium, present in the periphery of the pith of 6 species of *Pilea* examined by Guérin. Contents said to resemble an oleo-resin.

WOOD (Fig. 300 C–I)

Vessels usually medium-sized (mean tangential diameter 100–200 μ), but large in some species of *Boehmeria* and *Laportea* and occasionally moderately small; solitary and in small multiples of 2–4 cells, the solitary vessels often predominant; typically few, 1–6 per sq. mm., but 15 or more per sq. mm. in some species of *Boehmeria*, *Leucosyke*, and *Touchardia*; spiral thickening reported by Record (1851, 1868) in some species of *Leucosyke*, *Myriocarpa*, and *Urera*. Perforations simple. Intervascular pitting alternate and large, very occasionally tending to be elongated; pits to ray and wood parenchyma simple or almost so, and typically wide and elongated (Fig. 300 I), or unilaterally compound. Thin-walled tyloses often present and sometimes abundant, e.g. in *Boehmeria*, *Leucosyke*, and *Pipturus*. Mean member length 0·2–1·0 mm., usually 0·3–0·5 mm., but longer in *Neraudia* and *Villebrunea*. **Parenchyma** commonly of 2 types: (*a*) with normally lignified walls, and paratracheal, and (*b*) with thin, unlignified walls, occurring as islands or bands in cross-section, the ray tissue included within such parenchyma usually unlignified also; this tissue disintegrates readily, leaving almost-separated layers of fibres in a manner resembling certain woods with included phloem (see Fig. 300 C and E); both types of parenchyma present in *Gyrotaenia* (1851), *Laportea*, *Myriocarpa*, *Touchardia*, *Urera*, and *Urtica dioica* L. (2158); only normally lignified parenchyma present in the other genera, usually vasicentric (Fig. 300 D) or, more rarely, aliform, and sometimes with a few scattered cells in addition, but in broad confluent bands in *Obetia madagascariensis* (Juss. ex Poir.) Wedd. (Fig. 300 F), scanty in *Leucosyke*; Janssonius (1154) refers to short metatracheal lines in *Laportea stimulans* Miq. and Tippo to terminal bands in a single species. Sometimes containing solitary crystals, e.g. in *Urera* and *Urtica*; druses observed in *Urera caracasana* Jacq. et Gris. and raphides reported (959) in the unlignified parenchyma of several species of *Laportea*; storied and with numerous fusiform cells in *Laportea*, *Touchardia*, and *Urera*; strands usually of 2 cells in these genera and of 4 cells in the others. **Rays** up to 5–10 cells wide; Solereder quotes Engler as stating that the rays of *Gesnouinia arborea* Gaud. are narrow; usually 1 to several mm. high; uniseriates typically very few or absent, but numerous in some species of *Leucosyke*, *Maoutia*, *Urtica*, and *Villebrunia*, and composed of square to upright cells; typically 1–3 rays per mm., but about 10 per mm. in species with uniseriates; most commonly composed entirely or almost entirely of square and upright cells, but normally heterogeneous (Kribs's Type I ?), with central procumbent cells and marginal rows of square or upright cells in *Laportea*, *Pipturus* (1206), *Urtica*, and *Villebrunia*, and commonly with 10 or more marginal rows in some species of *Laportea* and *Villebrunia*; with sheath cells except in *Urtica* and *Villebrunia*. Often containing numerous solitary crystals and with druses in some species of *Boehmeria*. Not storied, even where all the other elements are storied. **Fibres** typically with simple pits, but occasionally with very small bordered pits, e.g. in *Laportea*, the pits usually numerous in both radial and tangential walls, but sometimes fewer in the radial walls. Septate in *Boehmeria*, *Debregeasia* (1206), *Leucosyke*, *Maoutia* p.p. (1206), *Myriocarpa*, *Pipturus*, and *Villebrunia* p.p. (1154). Storied in *Laportea*, *Touchardia*, and *Urera*. Janssonius refers to occasional solitary crystals in the septate fibres of *Pipturus incanus* Wedd. Mean length 0·75–1·5 mm.

TAXONOMIC NOTES

(i) FROM GENERAL ANATOMY

According to Guérin (836) the occurrence of laticiferous elements in *Laportea* and *Urera* suggests that these genera may have affinities with the Euphorbiaceae. Guérin also refers to the old opinion of Weddell (2382), based on the evidence provided by exomorphic features, that there are affinities between the Urticaceae and Tiliaceae. Guérin then emphasizes how the nature of the fibres, the occurrence of mucilage cells, and other microscopical characters point to the same conclusion. Holm (1014) has also drawn attention to the anatomical similarities between the Urticaceae and Tiliaceae. To the present writer the similarities between the 3 families seem rather striking, but a more detailed survey would be necessary before expressing a more definite opinion. It is interesting that Satake (1997) and Bigalke (198) both found parallelisms between the features of spodograms of the leaves and the generally accepted subdivisions of the family based on exomorphic features. The agreement is not, however, exact.

(ii) FROM WOOD STRUCTURE

Garratt (747A) notes a close similarity between the woods of this family and that of *Peumus* of the Monimiaceae, though other genera of the Monimiaceae are quite distinct.

Tippo (2261) considers that the Urticaceae are more highly specialized than the Moraceae on account of the higher percentage of forms with septate fibres and storied structure, the shorter vessel members and more nearly horizontal end-walls, and, finally, the occurrence of zones of unlignified parenchyma. There are some features that might indicate the reverse, but he considers these to be associated with the shrubby habit of most of the Urticaceae.

ECONOMIC USES

Several members of the family yield strong fibres. Of these, the most important is Ramie (*Boehmeria nivea* Gaud., especially the variety *tenacissima*) which is native of tropical Asia, but cultivated in other sufficiently warm regions. Good-quality samples of the fibre when prepared or 'cottonized' are white and silky, but those of poor quality tend to be yellowish. Individual cells described (Wiesner 2423) as 120–150 mm. long, but sometimes attaining as much as 260 mm.; maximum diameter 40–80, mostly about 50 μ; tapering towards the ends but the apices themselves rounded; generally flattened; lumen varying in diameter throughout the length of the cell, often containing granular, starchy material; cell walls moderately thick, but less than the breadth of the lumen, exhibiting longitudinal fissures and transverse clefts. Fibres swelling and becoming blue when treated with cuprammonia. Walls becoming yellow and contents golden-brown to blue-black when treated with iodine.

The fibre of the stinging-nettle (*Urtica dioica* Linn.) has aroused interest from time to time, and its properties were reinvestigated at Kew and collaborating institutions during the Second World War. The fibre is remarkable for its high tensile strength and the fact that its cell walls are unlignified. Difficulties of cultivation and extraction, as well as the small amount of fibre in the stem, have so far prevented its use in commercial quantities except for local industries or as a war-time measure, chiefly on the European continent. The fibre, which is white and silky when well prepared, is characterized microscopically by a very variable appearance in transverse sections, the cells being circular, polygonal, or flattened. Other features include moderately thick but distinctly pitted walls; circular to somewhat flattened and angular lumina in the centre of the fibre cells, the narrow lumina appearing as fine lines towards the ends of the cells; frequent granular contents in the lumina. Ultimate fibre cells described (Wiesner 2423) as 23–56 mm. long; ends tapering considerably, but apices sometimes swollen and rounded; cell walls longitudinally and diagonally striated. Ultimate fibre cells measured at Kew ranged from 1·7 to 4·4 cm., a few exceptional cells attaining a length of up to 10 cm. Measurements at Kew also showed that the length of the fibre cells varies in different parts of an individual plant, being greatest at the base of the main stem. Besides being a source of fibre, *Urtica dioica* is used in commercial quantities for the extraction of chlorophyll from the leaves, whilst rayon has been prepared on a laboratory scale from the woody centre of the stem left over after removal of the pericyclic fibre.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Almost if not quite every genus has been examined, especially for the presence of cystoliths (see references in text). The genera represented in the Kew slide collection are Boehmeria, Debregeasia, Laportea, Parietaria, Pilea, Urera, Urtica.

(ii) FOR WOOD STRUCTURE

Boehmeria, (Debregeasia), (Gyrotaenia), Laportea, (Leucosyke), Maoutia, Myriocarpa, Obetia, Pipturus, Touchardia, Urera, (Urtica), Villebrunia.

LITERATURE

(i) *On General Anatomy*

Bigalke **198**, Flury **688**, Guérin **833**, **834**, **835**, **836**, Holm **1014**, Kuster **1310**, Losch **1391**, Mohler **1544**, Nestler **1586**, Pfeiffer, H. **1707**, Satake **1997**, Sayeedud-Din and Abdus Salam **2015**, Scott **2073**, Varossieau **2324**, Weddell **2382**, Wiesner **2423**, Wille **2425**.

(ii) *On Wood Structure*

den Berger **182**, Brown, F. B. H. **282**, Burgerstein **310**, **312**, Chalk and Chattaway **362**, Cozzo **494**, Garratt **747A**, Hess **959**, Howard **1088**, Isenberg **1124**, Janssonius **1154**, Jones **1191**, Kanehira **1206**, Lecomte **1334**, Pearson and Brown **1679**, Record **1843**, **1851**, **1868**, Record and Hess **1886**, Stone **2202**, Tippo **2261**, Varossieau **2324**, Williams **2430**.

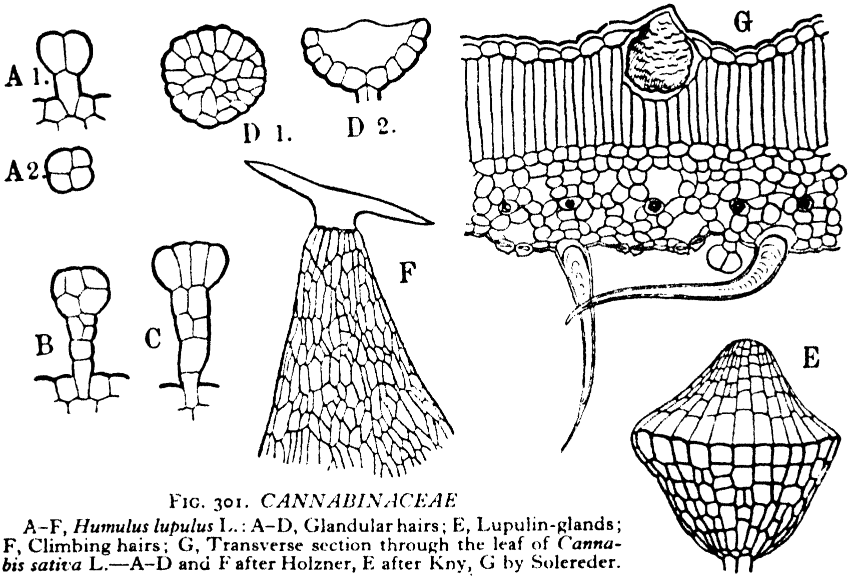


FIG. 301. *CANNABINACEAE*
A–F, *Humulus lupulus* L.: A–D, Glandular hairs; E, Lupulin-glands; F, Climbing hairs; G, Transverse section through the leaf of *Cannabis sativa* L.—A–D and F after Holzner, E after Kny, G by Solereder.

248. CANNABINACEAE

(FIG. 301 on p. 1254; FIG. 305 on p. 1274)

SUMMARY

A north temperate family of erect or climbing herbs belonging to the genera *Cannabis* and *Humulus*. The surface of the plants is covered with glandular and non-glandular **hairs. Cystoliths** and similar bodies are associated with the non-glandular types, or the walls of the hairs may exhibit varying degrees of silicification even when cystoliths are absent. The **pericycle** and secondary **phloem** of the axis contain abundant fibres with cellulose walls. Structures usually described as **laticiferous canals** occur in the phloem of both genera.

LEAF

Dorsiventral (Fig. 301 G). **Hairs.** (A) Non-glandular types (Fig. 301 G) mostly unicellular, more rarely uniseriate; often containing **cystoliths** of various sizes. Cystoliths in the swollen basal part of the hairs sometimes penetrate into the mesophyll (Fig. 301 G). Walls of the hairs frequently silicified, even in the absence of cystoliths. Unicellular, 2-armed hairs, situated on multicellular pedestals (Fig. 301 F) or attached directly to the epidermis, present in *Humulus*. (B) Glandular hairs (Fig. 301 A–E) include the following types: (i) Capitate, with unicellular, uniseriate or partially biseriate stalks, and spherical heads of 4 or more cells. (ii) Discoid glands with unicellular stalks. (iii) Glands with crateriform heads with abundant secreted material beneath the epidermis. Teeth of the young leaf of *Humulus* provided with a glandular, palisade-like epidermis. **Stomata** ranunculaceous. **Petiole** (Fig. 305 F, H), in transverse sections through the distal end, exhibiting a deep crescent of widely spaced vascular strands in *H. lupulus* Linn. (Fig. 305 H) and a fairly deep, continuous, crescentic vascular strand with strongly incurved ends in *Cannabis sativa* Linn. (Fig. 305 F). Vessels in the xylem of the petiole, especially in *Cannabis*, arranged in short, crowded, radial rows. Mechanical support provided by sub-epidermal collenchyma. Tubular structures, variously described as **laticiferous** or **resin-canals,** present in the phloem of *Cannabis*. For further particulars see under 'Stem'.

AXIS

STEM (Fig. 305 G, I, J)

Cork arising superficially in *Cannabis*. Primary **cortex** very narrow. **Pericycle** of *Humulus* including an almost continuous, fairly broad ring of fibres. A large proportion of the fibres in the stem of *Cannabis* visible, in transverse sections, as irregular groups embedded in triangular masses of tissue with outwardly directed apices (Fig. 305 I). Triangular fibrous zones probably pericyclic, but not very sharply differentiated from the secondary **phloem** which also contains fibres, the latter tending to be arranged in tangential bands in old stems. Pericyclic and phloem fibres with cellulose walls. Primary **xylem** groups in *Humulus lupulus* Linn. sharply demarcated from the continuous cylinder of the later-formed secondary xylem; vessels in the primary xylem arranged in short radial multiples (Fig. 305 J), diameter of individual members up to about 90 μ. Vessels of the secondary xylem of the same species solitary and in irregular clusters; radial diameter of the larger solitary members up to about 180 μ. Vascular system, in transverse sections of young stems of *Cannabis* (Fig. 305 G), at first appearing as a sinuous ring of slightly separated bundles, the primary xylem including crowded vessels in very definite radial rows. Xylem in older stems of *Cannabis* forms a wide, continuous cylinder traversed by amyliferous medullary rays 1–3 cells wide, vessels oval, solitary, in radial pairs, or variously shaped groups of 3–6; radial diameter of individual vessel members up to about 90 μ; pits to adjacent parenchymatous cells simple. Vessel perforations in both genera simple, usually horizontal, but occasionally slightly oblique. Groundwork of xylem in both genera composed of thin-walled, somewhat angular fibres with tapering ends. **Pith** smaller in *Cannabis* than in *Humulus*, in both genera composed of thin-walled cells, the centre becoming hollow. Structures variously described as **laticiferous** or **resin-canals,** with granular contents, present in the phloem of both genera. Latex of *Humulus* stated by Solereder to be rich in tannin and to contain colourless, spherical or biconvex grains, possibly consisting of protein. Latex canals in *Cannabis* consisting, according to Zander (2503), of cylindrical, unsegmented, unbranched elements that are situated in the phloem in most parts of the plant, but said to be absent from the roots, cotyledons, and greater part of the hypocotyl; those in the leaf not always directly connected with those in the stem. Latex canals of *Cannabis* are initiated just behind the growing apex of the stem after the formation of the leaf rudiments, their subsequent development keeping pace with that of the shoot by stretching and probably by apical growth. Contents of the latex described by Zander as a yellowish-brown, horny mass. **Crystals** in *Cannabis* fairly plentiful in the phloem; cluster and sphaerocrystals noted in the peripheral part of the pith, and occasional solitary types in some of the medullary ray cells of *Cannabis* and in the xylem parenchyma of *Humulus*. Structures resembling **cystoliths,** similar to those described under 'Leaf', also occur in the stem.

ECONOMIC USES

The use of hops, which are the fruit-heads of *Humulus lupulus* Linn., for flavouring beer and similar beverages is well known, and the plant is cultivated in many European countries for this purpose. The fibre from the pericycle and phloem has also been used from time to time for the manufacture of textiles and paper, but is not very popular owing to the difficulty of removing it from the stem on a commercial scale. The microscopical structure of the fibre is well known (Wiesner 2423). Pericyclic fibres usually solitary, but those of the secondary phloem grouped in bundles. Primary fibres about 12 mm. long and 27 μ wide; appearing somewhat tangentially flattened in transverse sections, and showing wide lumina when viewed longitudinally; ends rounded; middle lamellae generally invisible. Individual fibres in the secondary bundles small, circular to polygonal in transverse section; about 7 mm. long and 21 μ wide; lignified middle lamellae conspicuous. Unbleached commercial fibre is stained blue, sometimes tinged with violet, by chlor-zinc-iodide, and a weak violet-red by phloroglucin and hydrochloric acid. Primary fibres unlignified. Fibres exhibit barrel-shaped swellings when treated with cuprammonia. Remnants of dark-brown unsegmented latex canals, fibres from the xylem, crystals of calcium oxalate, cork, 2-armed hairs, and pitted vessels often present amongst the genuine bast fibres.

Hemp fibre, derived from staminate plants of cultivated varieties of *Cannabis sativa* Linn., is of considerable importance particularly for making ropes and string, &c. It consists mainly of the phloem fibres, but in some samples remnants of parenchyma, xylem, and integumentary tissues may be seen. Ultimate fibre cells commonly 5–55 mm. long, but cells up to 10 cm. long also reported to occur by Hayward (927). Fibre cells, in transverse section, 3–7 sided with rounded corners, the middle lamella and rather obscure primary membrane appearing yellow when treated with iodine and sulphuric acid, the inner membrane being conspicuously stratified, the stratifications appearing as longitudinal striations in cells lying on their sides. Swellings and transverse fissures also common in longitudinal view. Lumen, in transverse sections, frequently flattened and often with clefts and indentations; appearing very variable in width throughout the length of each cell when lying on its broad side, but uniformly narrow in cells resting on their narrow edges. Ends of some of the cells tapering to fine points, apices of others blunt or sometimes bifurcated. Innermost layer of the fibre frequently appearing as a sinuous tube after treatment with cuprammonia. Important diagnostic characters in some samples are particles of stem surface that are devoid of stomata, but bear usually curved, conical, warty, easily detachable hairs, which leave scars surrounded by circles of radially arranged cells when they fall off, and the occurrence of crystals.

Hemp fibre is difficult to distinguish from flax (*Linum usitatissimum*, Family Linaceae) as has been shown by Korn (1268), Sonntag (2166), Schilling (2031), and others. The last author demonstrated that the frequency of bifurcated cell endings in hemp varies in different parts of the plant, and is also governed by variations in the harvesting, retting, and manufacturing processes. This feature is, therefore, of less diagnostic value than was at one time supposed. The following are some of the characters whereby hemp and flax fibres may sometimes be distinguished (Wiesner 2423). Flax fibre treated with chlor-zinc-iodide shows, in longitudinal view, reddish-violet walls, a sharply defined, narrow lumen, the latter usually with yellow, filamentous contents. Hemp fibre, when similarly treated, shows dirty, reddish-violet or sometimes greenish walls, whilst the lumen is much less sharply defined than in flax and contains less frequent contents which are yellow and granular. Transverse sections of flax treated with the same reagent show only a small proportion of the cells surrounded by yellow outer membranes, whereas, in hemp, most of the cells exhibit this feature. Flax fibres, in transverse section, are more sharply polygonal than those of hemp, whilst the lumen of flax is more punctiform and the inner layer of the walls less distinctly laminated. The longitudinal striations in flax appear as a left-handed spiral, more clearly visible than the right-handed spiral striations of hemp.

The mode of development of hemp fibres has been described by Kundu (1302), and their X-ray structure by Kundu and Preston (1304). According to Nassanov (1579) there are 3 main types of hemp. Japanese with 6 leaf-traces, the Italian with 8, whilst the third kind has multiple leaf traces in the upper part of the stem. The same author has described certain wild forms which have a higher fibre content than some of the cultivated varieties.

The dried flowering and fruiting tops of the pistillate plant of *Cannabis sativa* have strong narcotic properties, and are used in medicine. Hemp seeds contain oil, and are also used as bird food.

TAXONOMIC NOTES

The anatomical structure has many points in common with that of the Urticaceae and Moraceae, which are generally accepted as closely related. See also p. 1269.

GENERA DESCRIBED

Cannabis,* Humulus.*

* Represented in the Kew slide collection.

LITERATURE

On General Anatomy

Hayward 927, Korn 1268, Kundu 1302, Kundu and Preston 1304, Nassanov 1579, Schilling 2031, Sonntag 2166, Varossieau 2324, Wiesner 2423, Zander 2503.

249. THELYGONACEAE

(CYNOCRAMBACEAE)

SUMMARY

A small family of fleshy herbs from the Mediterranean region and Far East, comprised in the single genus *Thelygonum* (*Cynocrambe*). The more interesting anatomical features include the rubiaceous **stomata;** the absence of **mechanical tissue** other than that which is provided by the xylem; the fact that **chlorophyll** is more abundant in the pith than in the cortex of the axis; the presence of idioblasts containing **raphides** in both leaf and stem; the absence of other kinds of crystals. The morphology and anatomy of the genus have been described by Schneider (2045) and Ulbrich (2310).

LEAF

Dorsiventral. Large, club-shaped **glands** abundant in the region of the stem apex. Cells of the upper **epidermis** papillose; those of the lower epidermis with sinuous anticlinal walls; chlorophyll present in the epidermis on both surfaces. **Stomata** more numerous on the lower than on the upper surface; rubiaceous according to Schneider. **Mesophyll** including 2 layers of palisade cells. Vascular bundles of the **veins** not accompanied by sclerenchyma. **Petiole** supplied by an arc of 3 separate vascular bundles throughout its length. **Crystals.** Large idioblasts filled with raphides present in the spongy mesophyll; no other types recorded. **Tanniniferous substances** present in the cells of the upper epidermis.

AXIS

STEM

Hairs short, unicellular; no other types recorded apart from the glands mentioned under 'Leaf'. **Stomata** rubiaceous. Primary **cortex** composed of large, thin-walled cells, containing little chlorophyll, and devoid of collenchyma or other mechanical elements. **Endodermis** consisting of thin-walled cells apart from the casparian thickenings. **Phloem** in the form of small strands of cells with thin walls. **Xylem** forming a continuous cylinder; including radial rows of very numerous, small vessels. **Pith** containing much more chlorophyll than the cortex, especially in the peripheral part bordering on the xylem cylinder. Chlorophyll also present but less plentiful in the centre of the pith. Schneider and Ulbrich both point out that the peculiar distribution of the chlorophyll is somewhat similar to that in *Tilia.* Pith becoming hollow in old stems. **Crystals.** Idioblasts containing raphides present in the cortex.

TAXONOMIC NOTES

The taxonomic position of *Thelygonum* has been much disputed. Schneider (2045) and Ulbrich (2310), on exomorphic rather than anatomical grounds, suggest that the Thelygonaceae may be related to the Haloragaceae and in particular to *Hippuris*. *Thelygonum* has no important anatomical features in common with the Urticaceae, in which family it was included in the Bentham and Hooker system.

GENUS DESCRIBED

Thelygonum (Cynocrambe).

LITERATURE

On General Anatomy
Schneider **2045**, Ulbrich **2310**.

250. MORACEAE

(FIG. 299 on p. 1248; FIG. 302 on p. 1262; FIG. 303 on p. 1264; FIG. 304 on p. 1266)

SUMMARY

(i) GENERAL

A mainly tropical family consisting mostly of trees and shrubs, but a few members are somewhat woody herbs. Some species of *Ficus* show a remarkable development of aerial roots, and they may start life as epiphytes. The initially saprophytic mode of establishment of an epiphytic *Ficus* has been described by Chodat and Vischer (401). The leaf is usually dorsiventral, but, in some species, the palisade cells are low, whilst in others the whole mesophyll consists of palisade elements. The **hairs** include glandular and non-glandular types. The non-glandular types vary in length and in the number of component cells, but are often short or resemble papillae. Glandular spots sometimes occur on the leaf-surface as well. The **epidermis** of the leaf consists of 1 to several layers of cells. Occasional, thin, vertical partitions to the epidermal cells also recorded. An epidermis of several layers of cells is not to be confused with true **hypoderm,** which also occurs in certain genera. The cell walls are often silicified or calcified, especially in the hairs and epidermal tissues, but more deeply seated cells are also affected at times. This likewise applies to cells with mucilaginous walls which occur most frequently in the epidermis. **Cystoliths** are also fairly common. **Stomata** are rather variable in their distribution, in the extent to which raised above or depressed below the leaf-surface, and in the nature of the surrounding epidermal cells.

The **mesophyll** of a few genera contains sclerenchymatous idioblasts. The **veins** are variable in structure and sometimes vertically transcurrent. There are also considerable variations in the structure of the **petiole. Secretory canals,** which may be laticiferous or filled with gum-resin or mucilage, are widely distributed in both leaf and axis. Statements in the literature do not always make it easy to differentiate between these categories of secretory elements. The young stem contains a varying abundance of fibres in the **phloem.** The outer part of the wall of the phloem fibres is of a different consistency from, and serves to envelop, the inner portion. The **pericycle** is usually marked by separate strands of fibres which are frequently unlignified. The **cork** arises superficially, whilst the primary **cortex** is often extensively sclerosed or contains stone cells. **Crystals** are secreted mostly in the form of clusters, solitary types being less frequent. They are sometimes situated in idioblasts.

(ii) WOOD

Vessels usually medium-sized to large and predominantly solitary, typically few, occasionally ring-porous and with spiral thickening, perforations simple, intervascular pitting minute to large, pits to parenchyma usually round to elongated, members of medium length to extremely short. **Parenchyma** typically paratracheal, usually aliform to confluent, sometimes forming regular bands. **Rays** 1–15 (mostly 3–6) cells wide, usually slightly heterogeneous to homogeneous, with few and low uniseriates, but more markedly heterogeneous in a few species. **Fibres** with simple or very small bordered pits, often septate, usually of medium length to moderately short. **Latex tubes** present in the rays of many genera.

LEAF

Usually dorsiventral, but the lowest layers of the mesophyll differentiated as short palisade cells in species of *Ficus* belonging to the section *Urostigma* according to Solereder, and in species of *Broussonetia* and *Morus*, according to Mohler (1544). The entire mesophyll sometimes consists of palisade elements in *Antiaris*, *Brosimum*, *Ficus* (section *Urostigma*), and *Pourouma*. Arm-palisade cells recorded in *Parartocarpus*. Spongy tissue resembling hyphae recorded by Solereder in species of *Artocarpus* (section *Jaca*) and in certain species of *Ficus* (section *Urostigma*). The 2 lowest layers of spongy tissue provided with thick, pitted walls and resembling a hypoderm in *Parartocarpus excelsa* Becc. **Hairs** including both glandular and non-glandular types. (A) Unicellular, non-glandular hairs occur widely; sometimes very short and globose or resembling papillae; frequently silicified. Unicellular, bracket hairs recorded in *Artocarpus*, *Brosimum*, *Broussonetia*, *Cecropia*, *Dorstenia*, *Lannesania*. Bicellular hairs stated to occur in *Cudrania* and *Myrianthus*, and uniseriate types in species of *Cecropia*, *Ficus*, *Parartocarpus*, and other genera. Variations and peculiarities in the shape of the hairs are sometimes valuable for identification of genera and species, e.g. (i) Long, clothing hairs with basal pedestals of epidermal cells in *Castilla*, *Ficus*, &c. (ii) Hairs with a swollen base extending into the mesophyll in *Helicostylis poeppigiana* Trec. (B) Glandular hairs, provided with stalks consisting of 1 or more cells and variously shaped, generally multicellular heads, stated to occur in all of the investigated genera of Artocarpeae and Conocephaleae, as well as in *Antiaris*, *Artocarpus*, *Broussonetia*, *Dorstenia*, *Maclura*, and *Morus*. Most glands in the Artocarpeae with unicellular stalks; always occurring in isolation and not in groups; heads spherical or ellipsoidal with longitudinal and transverse walls. Glands with longer stalks recorded amongst the Artocarpeae only in *Ficus*, and antler-shaped types in *Sparattosyce*. In the Conocephaleae the lower surface of the leaf generally bears isolated, uniseriate, bent glands, notably in *Cecropia*, *Coussapoa*, *Musanga*, *Myrianthus*, *Pourouma*. Glands in *Conocephalus*, on the other hand, provided with unicellular stalks and arranged in groups of 2–5, the shape of the heads varying in different species. Groups of 2–7 glands recorded on the upper surface of the leaf in *Musanga*, *Myrianthus*, *Pourouma*. Large, ovoid or pear-shaped, multicellular, deciduous pearl-glands, often containing protein and oil, present in *Cecropia*; those on the lower surface of the base of the petiole situated amongst a velvety covering of uniseriate hairs. The apex of each pearl-gland communicates with the exterior via a stoma. Leaf-teeth glandular in *Morus*. Glandular spots, sometimes described as wax glands, present in the leaf in many species of *Ficus* (all sections), occurring especially on the lower surface of the leaf, either singly on the midrib and at the base of the lamina, or in the angles between the lateral veins of the first order and the principal vein. An unpaired wax gland nearly always present at the base of the midrib in species of *Ficus* (section *Urostigma*). Wax glands provided with palisade epithelium but no stomata.

Epidermis usually consisting of a single layer of cells, but frequently 2- or 3-layered, either locally or throughout the leaf. A small proportion of the upper epidermal cells horizontally divided in species of *Antiaris*, *Brosimopsis*, *Castilla*, *Cecropia*, *Dammaropsis*, *Ficus*, *Myrianthus*; structure of the lower epidermis similar in a few species of *Conocephalus* and *Ficus*. Cells of the epidermis provided with thin vertical walls in species of *Artocarpus*, *Brosimopsis*, *Poulsenia*; with delicate, parallel striations in species of *Ficus* and *Parartocarpus*; with irregularly distributed, coarse crests of cuticle in some species of *Ficus*. Various types of epidermal papillae stated to occur in *Brosimum* (numerous species), *Ficus*, *Helicostylis*, *Myrianthus*. Epidermal cells with mucilaginous inner walls recorded on the upper surface of species of *Antiaris*, *Artocarpus*, *Bosquiea*, *Brosimopsis* (outer wall also mucilaginous), *Brosimum*, *Cecropia*, *Helicostylis*, *Morus*, *Olmedia*, *Perebea*, *Pseudolmedia*. Similar mucilaginous cells also occur in the hypoderm (see below) beneath the adaxial surface of the leaf in *Balanostreblus*, *Cecropia*, *Conocephalus*, *Coussapoa*, *Musanga*. Outer walls of the epidermal cells often silicified (see below). **Hypoderm** reported to occur in certain species of *Artocarpus*, *Balanostreblus*, *Cecropia*, *Conocephalus* (2–3 layers), *Coussapoa*, *Ficus* (1–4 layers), *Musanga* (2 layers), *Pourouma* (1–2 layers), *Sahagunia*; generally occurring only beneath the adaxial surface except e.g. in *Ficus*. Hypoderm nearly always parenchymatous, but the component cells varying in size and in the nature of the walls; sometimes tending to be fibrous in *Artocarpus*, especially in *A. lanceaefolius* Roxb.

Stomata in the Artocarpeae and Conocephaleae nearly always confined to the lower surface, except in *Cecropia humboldtiana* Klotzsch.; sometimes raised on pedestals in species of *Cecropia*, *Coussapoa*, *Pourouma*, or sunk below the surface in *Brosimopsis* and *Ficus*; tending to be arranged in groups between the projecting network of veins on the lower surface of the leaf in many species of *Ficus*. Stomata cruciferous in *Conocephalus*; surrounded by a rosette of subsidiary cells with relatively thin inner walls in a few species of *Ficus*; ranunculaceous in certain other species. Relatively large stomata, resembling hydathodes, situated above the veins in a few species of *Brosimum* and *Ficus*. True **hydathodes,** appearing to the naked eye as spots, small pits, or warts, recorded on the upper surface, especially where the veins join one another, in species of *Cecropia*, *Conocephalus*, *Dammaropsis*, *Ficus*. Scattered hydathodes on the upper surface of the leaf of *Ficus javanica* Reinw. appear as orange-coloured spots according to Molisch (1548). Transverse sections show the palisade tissue to be replaced by small, parenchymatous cells filled with orange-red bodies resembling carotin, but hydathodes not coloured in young leaves of the same species. Numerous stomata present immediately above the red tissue, but absent from the remainder of the epidermis. The presence or absence of hydathodes said by Solereder to be of little diagnostic value owing to variations in their occurrence within a single species.

Mesophyll including sclerenchymatous idioblasts in a few species of

Balanostreblus, *Ficus*, and *Sahagunia*. **Veins** very diverse in structure. **Petiole** (Fig. 299 F, H–K, M), in transverse sections through the distal end of species examined at Kew, exhibiting a wide range of structure. A simple crescentic vascular strand with outwardly directed ends noted in *Cudrania* (Fig. 299 F); a shallow vascular arc with incurved ends in *Antiaris toxicaria* Lesch. (Fig. 299 M); a shallow abaxial arc accompanied by 2 small, adaxial strands in *Broussonetia papyrifera* Vent.; a crescent of individually distinct bundles with subsidiary strands in the 'medullary' position in *Brosimum alicastrum* Sw. (Fig. 299 J) and *Morus alba* Linn. (Fig. 299 K); an almost closed cylinder of xylem accompanied externally by numerous phloem groups

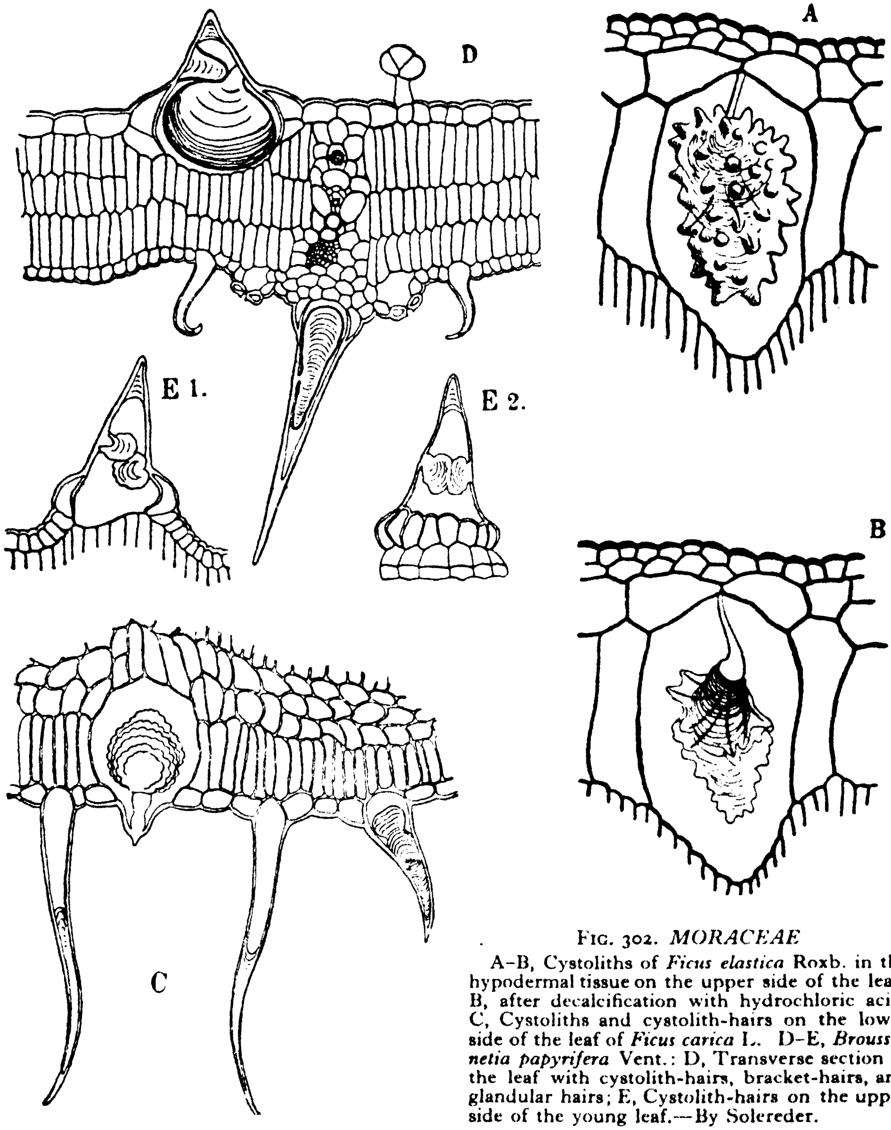


FIG. 302. *MORACEAE*

A–B, Cystoliths of *Ficus elastica* Roxb. in the hypodermal tissue on the upper side of the leaf: B, after decalcification with hydrochloric acid. C, Cystoliths and cystolith-hairs on the lower side of the leaf of *Ficus carica* L. D–E, *Broussonetia papyrifera* Vent.: D, Transverse section of the leaf with cystolith-hairs, bracket-hairs, and glandular hairs; E, Cystolith-hairs on the upper side of the young leaf.—By Solereder.

and, in the abaxial part of the pith, by other small phloem strands, a few of the latter being accompanied by a small amount of xylem, in *Ficus carica* Linn. (Fig. 299 I) and other species of *Ficus*; a U-shaped strand of xylem surrounded by a continuous cylinder of phloem and accompanied by a single 'medullary' bundle in *Maclura pomifera* (Raf.) Schneid. (Fig. 299 H). Other species of the above genera tend to be similar in structure. Vessels in the petiolar xylem usually in short, crowded, radial rows. Solereder records a circle of bundles in the petiole of species of *Castilla* and *Ficus*, a ring of 5–7 bundles in species of *Artocarpus*, *Broussonetia*, and *Maclura*, and about 30 separate bundles in *Cecropia peltata* Linn.

Crystals mostly secreted in the form of clusters in the Artocarpeae and Conocephaleae, but isolated types also occur, e.g. around the vascular bundles in species of *Antiaris*, *Brosimum*, *Ficus*, and *Morus*. Crystal idioblasts not uncommon in the palisade tissue, notably in the region of the vertically transcurrent veins of *Pourouma*. Solitary or groups of epidermal cells, each containing a single clustered crystal, recorded, especially in the neighbourhood of the veins, in *Antiaris*, *Artocarpus*, *Brosimopsis*, *Brosimum*, *Castilla*, *Cecropia*, *Cudrania*, *Dammaropsis*, *Dorstenia*, *Ficus*, *Maclura*, *Musanga*, *Olmedia*, *Perebea*, *Pourouma*, *Treculia*. Solitary crystals present in, and occupying the whole lumen of, small epidermal cells with thickened inner walls, especially in species of *Balanostreblus*, *Brosimum*, *Ficus*, *Sorocea*. Sphaerocrystalline masses of unknown chemical composition stated to occur in the mucilaginous epidermal cells of certain species of *Conocephalus*.

Silicified and calcified cell walls. Walls of the hairs and epidermal cells commonly silicified in the Artocarpeae and Conocephaleae; similar encrustations also occur in the spongy tissue of some of the older leaves of *Ficus*. Silicified pegs attached to the outer walls of the epidermal cells recorded in *Antiaris*, *Ficus*, *Poulsenia*; somewhat similar bodies also reported to occur in the hypoderm of *Ficus diversifolia* Bl., in the parenchyma accompanying the larger veins in various species of *Ficus* and also in *Parartocarpus* and *Sparattosyce*.

True **cystoliths** (Fig. 302 A–C) known to occur in *Broussonetia*, *Chlorophora*, *Conocephalus*, *Dammaropsis*, *Fatoua* (Satake 1997), *Ficus*, *Malaisia* (Satake 1997), *Morus*, *Poulsenia*, *Sparattosyce*, especially in the epidermis on 1 or both surfaces of the leaf according to the species; sometimes situated in idioblasts. These bodies exhibit considerable variations in size and shape, those of *Conocephalus* frequently 2-armed or stellate. Cystoliths absent from *Artocarpus* according to Satake (1997), who used the spodogram method of investigation. Structures resembling cystoliths (Fig. 302 C–E) also occur in the tips, or suspended from the walls, of the hairs in species of *Antiaris*, *Artocarpus*, *Broussonetia*, *Cecropia* (hairs sometimes filled with stratified siliceous material), and *Parartocarpus*. The mode of development of the cystoliths in *Ficus* has recently been discussed by Scott (2073).

Secretory elements. (A) Laticiferous elements (see also p. 1265), in the form of thin-walled sacs, recorded by Solereder in the leaf of all examined members of the Artocarpeae; present especially in the tissues around the veins, in the medullary tissue of the veins, sometimes extending into the mesophyll and occasionally to the hypoderm or even the epidermis. Unsegmented laticiferous elements, sometimes rather difficult to recognize, recorded by Mohler (1544) in species of *Antiaris*, *Artocarpus*, *Brosimum*, *Broussonetia*, *Dorstenia*, *Ficus*, *Maclura* (latex yellow in *M. pomifera* (Raf.) Schneid. (syn. *M. aurantiaca* Nutt.)), and *Morus*. Latex of the Artocarpeae said to include small masses of rubber accompanied by tannin. Latex of *Brosimum* and *Ficus elastica* Roxb. rich in magnesium salts, the latter crystallizing in the form of round or angular sphaerites from an exposed drop of latex. The frequent laticiferous elements in the stem of the Conocephaleae seldom extend into the leaf, although recorded in association with the veins in a few species of *Pourouma*. (B) Gum-resin and mucilage cells. Isolated, spherical or ellipsoidal cells with brownish contents having the nature of gum-resin, present in the spongy tissue of numerous species of *Artocarpus* (especially the sections *Jaca* and *Prainea*). Rows of mucilage cells recorded in the larger

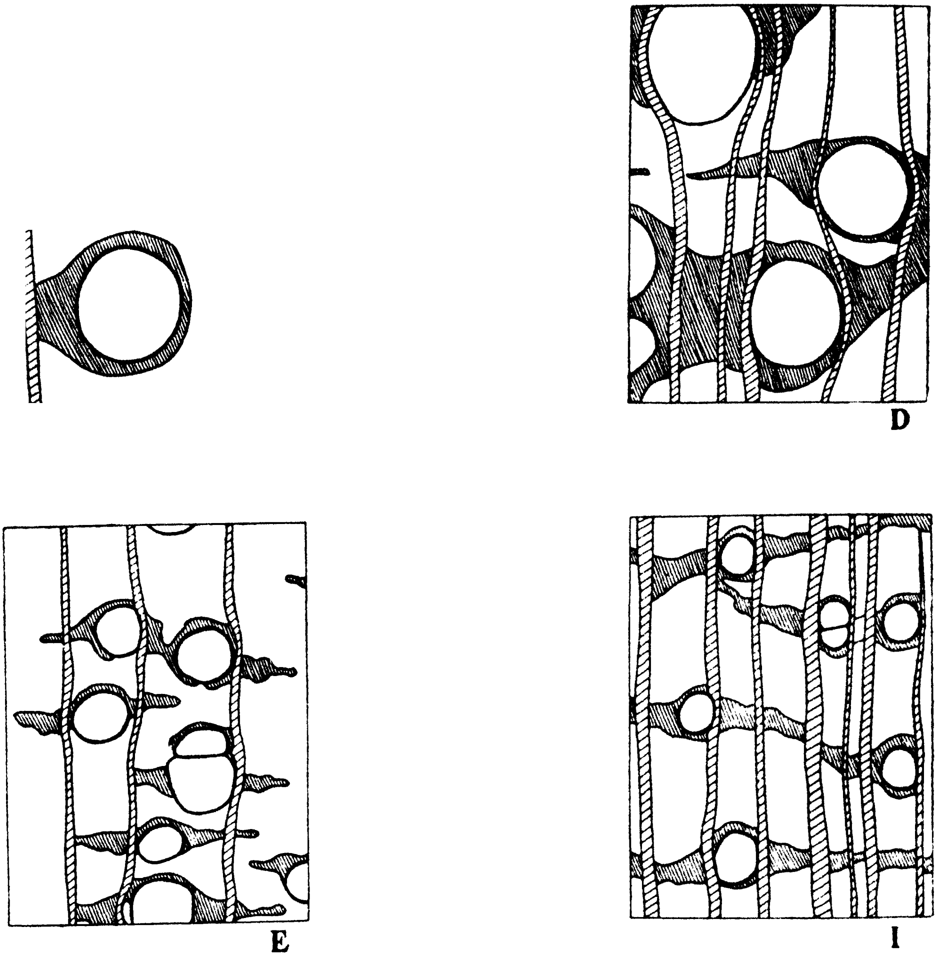


FIG. 303. *MORACEAE*

A, *Cecropia juranyana* Aladar. B, *Pseudostreblus indica* Bur. C, *Chlorophora excelsa* Benth. et Hook. D, *C. excelsa* Benth. et Hook. E, *Brosimum caloxylon* Standley. F, *B. caloxylon* Standley (showing latex tube). G, *Morus nigra* Linn. H, *Trophis* sp. I, *Trophis* sp.

lateral veins in species of *Cecropia*, *Conocephalus*, *Coussapoa*, *Musanga*, *Olmedia* (1 species), *Myrianthus*. (C) Tannin-idioblasts present in the palisade tissue in species of *Antiaris*, *Artocarpus*, *Brosimum*, *Conocephalus*, *Dammaropsis*, *Ficus*. For further details of leaf structure, including inter-specific differences for a few species, see Mohler's (1544) thesis.

AXIS

YOUNG STEM (Fig. 299 L)

Cork arising in or near the outermost layer of the cortex in all examined species of *Antiaris*, *Artocarpus*, *Brosimum*, *Broussonetia* (sometimes epidermal in this genus), *Cecropia*, *Ficus*, *Maclura*, *Morus*. Primary **cortex** becoming extensively sclerosed in *Artocarpus*, *Cecropia*, and *Ficus*; containing a ring of stone cells in a few species of *Chlorophora*, *Cudrania*, *Ficus*, *Morus*, *Streblus*. **Pericycle** including isolated strands of fibres, the individual elements often being broad and flattened as seen in transverse sections, and frequently unlignified. **Phloem** also containing fibres (Fig. 299 L), the latter varying in abundance and arrangement, and often of considerable length. Phloem stratified into hard and soft portions, e.g. in *Morus alba* Linn. and *Streblus asper* Lour. Outer part of the wall of the phloem fibres appearing as an envelope around the inner layers in *Antiaris*, *Artocarpus*, *Broussonetia*, *Cudrania*, *Ficus*, *Maclura*, *Morus*, *Olmedia*, *Streblus*. **Xylem** usually traversed by wide or fairly wide primary rays. Primary xylem tending to have vessels in short, radial rows. Secondary xylem in the form of a continuous cylinder in all of the species examined at Kew, but medullary rays broadening in the phloem in some species; vessel perforations simple. **Pith** commonly rather wide, usually composed of thin-walled cells, but peripheral part sometimes consisting of cells with thicker walls than those at the centre. Stalks of the **fruiting axes** described by Solereder as polystelic in *Artocarpus incisa* Linn. and *A. integrifolia* Linn.

Secretory elements. (A) Secretory cells, with unidentified but probably mucilaginous contents, noted at Kew in the cortex of species of *Antiaris*, *Brosimum*, *Ficus*, and *Morus*; in the phloem and medullary rays in the same species of *Ficus* and *Morus*, and in the medullary rays and pith of *Morus*. Many of the wood fibres and vessels in the innermost part of the xylem blocked with secreted material in *M. alba*. (B) Mucilage canals recorded in the primary cortex, and sometimes in the pith as well, in species of *Cecropia*, *Conocephalus*, *Coussapoa*, *Musanga*, *Myrianthus*. (C) Laticiferous elements, in some cases seen to be without anastomoses (see also p. 1263), present in the primary cortex, pericycle, primary and secondary phloem, and pith in many species of *Allaeanthus*, *Ampalis*, *Antiaris*, *Artocarpus*, *Bagassa*, *Balanostreblus*, *Bleekrodea*, *Brosimum*, *Broussonetia*, *Castilla*, *Cecropia*, *Chlorophora*, *Clarisia*, *Coussapoa*, *Cudrania*, *Dorstenia*, *Ficus*, *Lanessania*, *Maclura*, *Maillardia*, *Morus*, *Musanga*, *Myrianthus*, *Noyera*, *Olmedia*, *Pachytrophe*, *Paratrophis*, *Perebea*, *Pourouma*, *Pseudomorus*, *Sahagunia*, *Sloetia*, *Sorocea*, *Taxotrophis*, *Trophis*.

Solitary and clustered **crystals** present in the soft tissues of all of the genera examined at Kew, but their frequency and distribution varying in different species. Solitary crystals sometimes enclosed in cells with thickened, lignified walls, e.g. in the cortex of *Brosimum alicastrum* Sw. and *Morus* spp.

WOOD (Figs. 303 and 304)

Vessels usually medium-sized (mean tangential diameter 100–200 μ), large (more than 200 μ) in some species of *Artocarpus*, *Bagassa*, *Cecropia*, *Chlorophora*, *Musanga*, *Parartocarpus*, *Pourouma*, and *Prainea*, and small (less than 100 μ) in some species of *Craterogyne*, *Naucleopsis*, *Phyllochlamys*, *Pseudomorus*, *Sloetia*, *Taxotrophis*, *Treculia*, *Trophis*, and *Trymatococcus*; solitary vessels typically predominating, but some multiples of 2 or 3 cells always present and occasionally numerous, e.g. in some species of *Morus*, *Pseudostreblus*, and *Sloetia*; with an oblique pattern in *Maclura* p.p., *Morus* p.p., and *Prainea* and in almost 'ulmiform' bands in some specimens of *Maclura* (1886), *Morus* (particularly *M. alba* Linn.), and locally in *Broussonetia papyrifera*

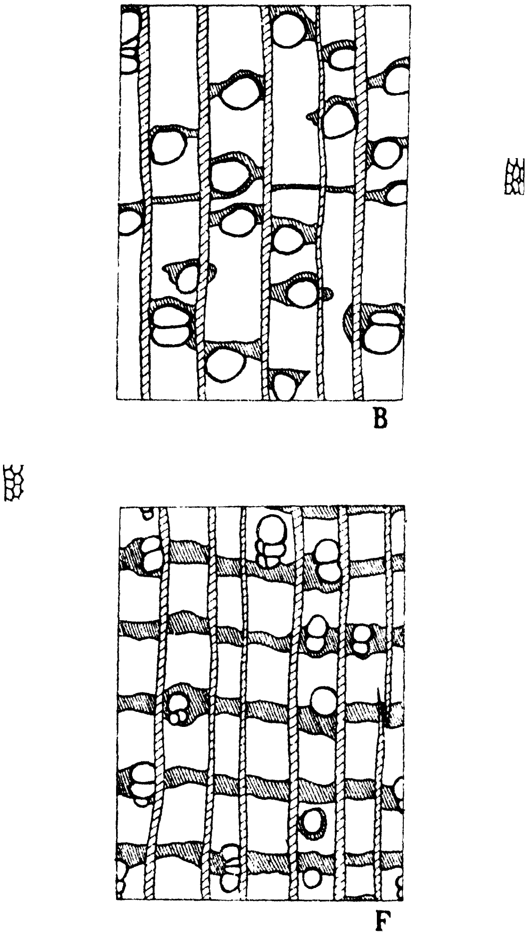


FIG. 304. *MORACEAE*

A, *Treculia africana* Decne. (with small latex tube). B, *Naucleopsis macrophylla* Miq. C, *Maclura pomifera* Schneid. D, *Broussonetia papyrifera* Vent. E, *Naucleopsis macrophylla* Miq. F, *Taxotrophis ilicifolia* Vidal. G, *Pseudomorus brunoniana* Bur. H, *Artocarpus bracteata* King. *l.* Latex tube.

Vent.; 1–25 per sq. mm.; very commonly less than 5 per sq. mm., e.g. in *Allaeanthus*, *Anonocarpus*, *Artocarpus*, *Bagassa*, *Brosimum*, *Cecropia*, *Chlorophora*, *Ficus*, *Gymnartocarpus*, *Helicostylis*, *Morus* (diffuse-porous species only), *Musanga*, *Myrianthus*, *Parartocarpus*, *Pourouma*, *Prainea*, and *Treculia*; ring-porous in some species of *Broussonetia* (1206), *Cudrania*, *Maclura*, and *Morus*; with spiral thickening (often limited to smaller vessels) in some species of *Broussonetia* (1206), *Chlorophora* (1851, but not observed by the authors), *Cudrania*, *Maclura pomifera* (Raf.) Schneid. (syn. *M. aurantiaca* Nutt.) (2158), and *Streblus* (1851). Perforations exclusively simple. Intervascular pitting varying from very small, e.g. in *Allaeanthus*, *Craterogyne*, *Sloetia*, *Trophis*, and *Trymatococcus*, to large, e.g. in *Artocarpus*, *Cecropia*, and *Parartocarpus*; pits to ray and wood parenchyma typically larger than the intervascular pitting, often simple and elongated, but elongated pits rather uncommon in some species or specimens of *Artocarpus*, *Cudrania*, *Maclura*, and *Morus*. Tyloses often present and sometimes very abundant, occasionally pitted, e.g. in *Morus lactea* Mildbr.; sclerosed tyloses observed or reported (1449, 1886, 2261) in *Artocarpus* (*A. forbesii* King, 434), *Brosimum*, *Cudrania*, *Gymnartocarpus*, *Helianthostylis*, *Helicostylis*, *Paratrophis*, *Piratinera*, *Pseudolmedia*, and *Trymatococcus*; Tippo (2261) notes a correlation between thick-walled tyloses and the occurrence of thick-walled fibres, vessels, parenchyma, and ray cells; tyloses sometimes containing silica in *Artocarpus* (794). Solid contents often present; sometimes white; Gonggrijp (794) notes silica in *Artocarpus* spp. and *Sloetia elongata* Koord. Mean member length 0·15–0·6 mm. **Parenchyma** typically paratracheal; usually aliform or confluent or both; mostly vasicentric in *Cecropia* (Fig. 303 A), *Morus* p.p., *Musanga*, *Olmedioperebea* (1886), *Olmediophaena maxima* Ducke (1886), and *Pourouma guianensis* Aubl.; sometimes abaxial and aliform, e.g. in *Brosimum caloxylon* (Fig. 303 E), and *Naucleopsis* (Fig. 304 B); forming moderately regular confluent bands in some species of *Bosquiea*, *Castilla* (1886), *Clarisia*, *Coussapoa* (1886), *Gymnartocarpus*, *Maclura*, *Morus* (e.g. *M. lactea* Mildbr.), *Noyera* (1886), *Pourouma*, *Pseudolmedia*, *Pseudostreblus*, *Streblus*, and *Trophis* (Fig. 303 I) and sometimes, according to Record and Hess (1886), in *Brosimum*, *Helicostylis*, and *Ogcodeia*; in regular, narrow to broad bands, which cannot well be classified as confluent, in *Anonocarpus*, *Craterogyne*, *Ficus*, *Malaisia*, *Olmedia* (1886), *Phyllochlamys*, *Pseudomorus*, *Sorocea*, *Sparattosyce*, *Trophis* (1886), and *Trymatococcus*. Terminal bands sometimes present. Commonly containing chambered crystals of calcium oxalate and containing silica in *Artocarpus* spp. and *Sloetia elongata* (794). Strands most commonly of 2–4 cells, sometimes up to 8 cells, e.g. in some species of *Artocarpus*, *Ficus*, *Myrianthus*, *Parartocarpus*, and *Trymatococcus*; with some fusiform cells in *Cudrania tricuspidata* Bur. ex Lavallee and *Maclura pomifera* (Raf.) Schneid. Storied in occasional species of *Ficus*, e.g. *F. indica* L. and *F. vetusa* L. **Rays** most commonly up to 3–6 cells wide; exclusively uniseriate in some species of *Craterogyne* and *Trymatococcus*, seldom more than 2 cells wide in some species of *Helianthostylis*, *Pseudostreblus*, and *Sloetia*; sometimes up to 7–10 cells wide, e.g. in some species of *Broussonetia*, *Castilla*, *Ficus*, *Morus*, and *Myrianthus*; typically less than 1 mm. high, but rather higher in *Cecropia*, *Craterogyne*, *Ficus*, *Morus*, *Myrianthus*, and *Streblus*, and commonly more than 2 mm. high in *Nauclopsis*; uniseriates typically few and small and composed of mixed procumbent and square to upright cells, but sometimes moderately numerous, e.g. in species of *Brosimum*, *Cecropia*, *Myrianthus*, *Pourouma*, *Pseudomorus*, and *Treculia*, and then usually composed of square to upright cells only; 3–11, mostly 5–7, rays per mm.; usually heterogeneous (Kribs's Type II B or, less commonly, II A) with 1–3 (often only 1) marginal rows of square to upright cells, but commonly with 4 or more rows in some species of *Brosimum*, *Cecropia*, *Helicostylis*, *Malaisia*, *Pourouma*, *Pseudomorus*, *Treculia*, and *Trophis*; homogeneous (Kribs's Type I) in some species of *Artocarpus*, *Broussonetia*, *Castilla*, *Clarisia*, *Gymnartocarpus*, *Maclura*, and *Parartocarpus*; sheath cells rare, but occasionally present in some species of *Artocarpus* and *Ficus*. Record and Hess (1886) refer to the common occurrence of sclerotic cells in the most dense woods. Commonly with some solitary crystals in the ordinary cells and very occasionally with chambered crystals, e.g. in *Broussonetia papyrifera* Vent., *Cudrania tricuspidata*, and *Myrianthus libericus* Rendle. Storied in occasional species of *Ficus*, e.g. *F. altissima* Bl., *F. benjamina* L. (1781), and *F. indica* L. **Fibres** typically with small, simple pits, which are almost entirely limited to the radial walls, but with small, distinctly bordered pits in *Brosimopsis* (1886) and *Brosimum* p.p. and, according to Tippo (2261), with small borders in 44 out of the 100 species that he examined, including 8 species with septate fibres. Septate in at least some species of *Antiaris*, *Artocarpus* (*A. pomiformis* Teijsm. et Binn., 1154), *Brosimum*, *Castilla*, *Ficus*, *Mesogyne*, *Naucleopsis*, *Noyera*, *Ogcodeia*, *Olmedioperebea*, *Perebea*, *Prainea*, *Pseudolmedia*, and *Sparattosyce*. Walls rather thin to very thick, occasionally very thin, e.g. in some species of *Broussonetia* and *Cecropia* and in *Musanga*; sometimes with a gelatinous layer. Occasionally containing crystals in *Antiaris toxicaria* Lesch. (1154). Mean length 0·6–1·9 mm. **Latex tubes** (Figs. 303 F and 304 H) observed or reported (1886) in the rays of some species or specimens of *Acanthosphaera*, *Anonocarpus*, *Antiaris*, *Artocarpus*, *Bagassa*, *Bosquiea*, *Brosimopsis*, *Brosimum*, *Castilla*, *Chlorophora* (*C. tinctoria* (L.) Gaud. (2430)), *Ficus*, *Gymnartocarpus*, *Helicostylis*, *Naucleopsis*, *Noyera*, *Ogcodeia*, *Olmedia*, *Olmedioperebea*, *Olmediophaena*, *Parartocarpus*, *Perebea*, *Prainea*, *Pseudolmedia*, *Sloetia*, *Treculia* (rare), *Trophis*, and *Trymatococcus*. Tippo (2261) notes the absence of latex tubes from the sub-families Conocephaloideae and Cannaboideae. Coster (481) has investigated the development of the **growth rings** and seasonal cambial activity in *Morus alba* Linn. introduced into Java. Large deposits of calcium carbonate, or 'stone', sometimes occur in the wood of *Chlorophora excelsa* Benth. et Hook. f. (336, 908).

ROOT

Vascular cylinder of the aerial roots of *Cecropia* always appearing elliptical in transverse sections, even in roots with a circular outline according to Poulsen (1737).

PHYSIOLOGICAL ANATOMY

Stems of 'weeping' forms of *Morus alba* Linn. always differ from erect branches of the same species in containing a smaller amount of weaker mechanical tissue, according to Löw (1397). The anatomical structure and mechanism of the contractile roots of *Coussapoa schottii* Miq. have been described by Nordhausen (1605). Trülzsch (2285) has published a long, detailed account of the physiological anatomy of dorsally flattened shoots of *Ficus pumila* Linn.

TAXONOMIC NOTES

(i) FROM GENERAL ANATOMY

The structure has points in common with that of the Urticaceae, Cannabinaceae, and Ulmaceae, which are generally accepted as being related to the Moraceae.

(ii) FROM WOOD STRUCTURE

Tippo (2261) considers that the anatomy of the Moraceae is of rather a high type and that anatomical specialization in general has proceeded from the Moroideae to the Artocarpoideae, Cephaloideae, and Cannaboideae (= Cannabinaceae, see p. 1254) in that sequence. Though the Moroideae are on the whole the most primitive sub-family, the development of a pore zone in certain temperate species appears to have led to an acceleration of evolutionary development in these forms, so that they are more highly specialized than some of the species in the higher sub-families. The Cannaboideae, though ranked as the highest sub-family, have some primitive characters, such as small, angular vessels, and markedly heterogeneous rays; Tippo, however, considers that the retention of these features is due to all of the plants being herbs.

Discussing the tribes, Tippo notes that most of the species with septate fibres occur in the sub-family Artocarpoideae; septate fibres occur in only 1 genus of the Moroideae (*Mesogyne*) and are absent from the Fatoueae, Moreae, Broussonetieae, Strebleae, Euartocarpeae, Brosimeae, Conocephaloideae (except *Prainea*), and Cannaboideae and that these groups (except Broussonetieae, Euartocarpeae, and Brosimeae) also lack latex tubes. 'Fibre-tracheids' are regarded as characteristic of the Dorstenieae and most of the Euartocarpeae, and libriform wood fibres of the Brosimeae, Strebleae, Ficeae, and Cannaboideae.

ECONOMIC USES

The family is the source of several useful timbers. The most widely known of these are Iroko, *Chlorophora excelsa* Benth. et Hook. f., from tropical Africa, which is a strong, durable constructional timber that is well known to commerce, Snakewood or Letterwood, *Piratinera guianensis* Aubl., from Guiana, and Satiné, *Brosimum paraense* Huber, from French Guiana. Some of the woods are both strong and elastic, e.g. the Osage Orange, *Maclura pomifera* (Raf.) Schneid. and some species of *Morus*; Pearson and Brown (1679) note that the wood of *M. alba* Linn. is used in India for many of the purposes for which Ash is used in Europe. Other species of *Morus* and some species of *Artocarpus*, e.g. *A. heterophyllus* Lam., the Jak tree of Ceylon, produce useful light but durable timbers, which have a wide range of local uses.

Edible fruits derived from this family include the Bread Fruit (*Artocarpus incisa* Linn.), cultivated in the tropics; the Jack Fruit (*Artocarpus heterophyllus* Lam.), cultivated in tropical Asia; *Ficus carica* Linn., the edible fig of Europe; *Ficus sycamorus* Linn., the Egyptian fig; *Morus nigra* Linn., the Black Mulberry, widely cultivated in temperate regions. The seeds of *Treculia africana* Decne. are eaten in West Tropical Africa. The leaves of *Morus alba* Linn. are extensively used for feeding the larvae of the silk moth, whilst those of the North American Osage Orange (*Maclura pomifera* (Raf.) Schneid. (syn. *M. aurantiaca* Nutt.)) can be used for the same purpose. The latex of certain members of the family can be used as a source of rubber. Two of the best-known sources are *Ficus elastica* Roxb. from India and Malaya and *Castilla* (*Castilloa*) *elastica* Cerv., a large tree from Mexico, Honduras, &c. Neither of these plants is now of much importance as a source of rubber compared with the Para Rubber tree (*Hevea brasiliensis* Müll-Arg.—see Euphorbiaceae, p. 1231). The toxic juice of *Antiaris toxicaria* Lesch. was at one time used in Malaya as an arrow poison. The fibrous bark of the same species has also been used to make sacks, but the bark of the Paper Mulberry (*Broussonetia papyrifera* Vent.) is of much greater importance in the Far East, where it is used to make paper, whilst in the South Sea Islands a crude form of cloth is prepared from it.

The fibre of *Broussonetia papyrifera* consists (Wiesner 2423) of cells 7–21 mm. or occasionally up to 25 mm. long and up to 36 μ in diameter. Many of the cells thick-walled, the inner membrane appearing laminate and nearly always flattened in transverse sections; ends of these thick-walled cells usually pointed or, less frequently, rounded. Other cells also flattened, but provided with much thinner walls; resembling cotton fibres, and, like them, spirally twisted; ends of the thin-walled cells broad and rounded. Fibres unlignified; stained blue when treated with iodine and sulphuric acid; readily dissolved in cuprammonia. Primary membrane showing small, shortly elliptical pores arranged in a left-handed spiral; secondary membrane with elongated pores that are difficult to find. Other microscopical features include medullary ray tissue containing prisms of calcium oxalate 21–30 μ long; phloem parenchyma cells, some being crystalliferous; occasional remnants of laticiferous canals.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Allaeanthus, Ampalis, Antiaris,* Artocarpus,* Bagassa, Balanostreblus, Bleekrodea, Bosquiea, Brosimopsis, Brosimum,* Broussonetia,* Castilla (Castilloa), Cecropia, Chlorophora, Clarisia, Conocephalus, Coussapoa, Cudrania,* Dammaropsis, Dorstenia, Fatoua, Ficus,* Helicostylis, Lanessania, Maclura,* Maillardia, Malaisia, Morus,* Musanga, Myrianthus, Noyera, Olmedia, Pachytrophe, Parartocarpus, Paratrophis, Perebea, Poulsenia, Pourouma, Pseudolmedia, Pseudomorus, Sahagunia, Sloetia, Sorocea, Sparattosyce, Taxotrophis, Treculia, Trophis.

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

(Acanthosphaera), Allaeanthus, Anonocarpus, Antiaris, Artocarpus, Bagassa, Bosquiea, Brosimopsis, Brosimum, Broussonetia, Castilla, Cecropia, Chlorophora, Clarisia, Coussapoa, Craterogyne, Cudrania, Ficus, Gymnartocarpus, Helianthostylis, Helicostylis, Inophloeum, Maclura, Malaisia, Mesogyne, Morus, Musanga, Myrianthus, Naucleopsis, Noyera, Ogcodeia, (Olmedia), Olmedioperebea, (Olmediophaena), Parartocarpus, Paratrophis, Perebea, Phyllochlamys, Piratinera, Plecospermum, Poulsenia, Pourouma, Prainea, Pseudolmedia, Pseudomorus, Pseudostreblus, Sloetia, Sorocea, Sparattosyce, Streblus, Taxotrophis, Treculia, Trophis, Trymatococcus.

LITERATURE

(i) *On General Anatomy*

Chodat and Vischer 401, Hector 929, Löw 1397, Mohler 1544, Molisch 1548, Nordhausen 1605, Poulsen 1737, Rehder 1903, Satake 1997, Scott, F. M. 2073, Trülzsch 2285, Varossieau 2324, Wiesner 2423.

(ii) *On Wood Structure*

Alexandrov 14, Aubreville *et al.* 55, Beekman 167, Benoist 170, den Berger 179, 182, den Berger and Endert 183, Bianchi 194, Boulton and Price 245, Brit. Honduras For. Dept. 274, Brown, F. B. H. 282, Brown, H. P. and Panshin 288, 289, Burgerstein 310, Campbell and Fisher 336, Chalk and Rendle 365, Chowdhury 411, Cockrell 434, Cooper and Record 461, Coster 481, Dadswell 525, Dixon 592, Foxworthy 705, Giordano 786, Gonggrijp 794, Greguss 2522, Greiss 817, Harris 908, Hopkinson 1083, Howard 1088, Janssonius 1154, Jayawardana 1159, Jentsch 1173, Jones 1191, Kanehira 1206, 1209, Kribs 1283, Kurz 1309, Martin-Levigne 1449, 1450, Méniaud 1492, Normand 1611, 1619, Pearson and Brown 1679, Pfeiffer, H. 1712, Pfeiffer, J. Ph. 1713, Record 1781, 1783, 1801, 1809, 1818, 1835, 1836, 1843, 1851, Record and Hess 1886, 1887, Record and Mell 1894, Riera 1937, Stone 2202, 2206, Sudworth and Mell 2218, Tang 2230, 2231, Tippo 2261, Uspensky 2317, Varossieau 2324, Williams 2430, Yamabayashi 2478.

251. ULMACEAE

(FIG. 305 on p. 1274; FIG. 306 on p. 1276)

SUMMARY

(i) GENERAL

A mainly north temperate family of trees. The leaf is usually dorsiventral, although sub-centric in a few species. The **hairs** include both non-glandular and glandular types. The former are mostly simple and short, and consist of 1 to several thick-walled, often calcified or silicified cells. The glandular hairs vary in the length of the stalks and in the nature and shape of the heads. A few special types with a more limited distribution are described under 'Leaf'. The **stomata** are, in most instances, confined to the lower surface, but the surrounding cells do not exhibit any constant or characteristic arrangement. The cell walls, especially of the hairs and epidermis of both leaf and stem, are commonly silicified or calcified. **Cystoliths,** especially in the upper epidermis of the leaf, where they are frequently associated with the hairs, have been recorded in a few genera. **Mucilage cells** are fairly common in the mesophyll of the leaf as well as in the bark. **Crystals** include solitary and clustered types.

(ii) WOOD

Vessels predominantly solitary, in radial multiples, in ulmiform tangential lines or without distinctive arrangement, spiral thickening sometimes present, sometimes ring-porous, perforations simple, intervascular pitting alternate, small to moderately large, pits to parenchyma often large and elongated, members moderately to very short. **Parenchyma** paratracheal, scanty, vasicentric, confluent or in broad bands that appear almost apotracheal, storied in several genera. **Rays** up to 2–11 cells wide, heterogeneous to homogeneous, occasionally storied. **Fibres** typically with simple pits, usually of medium length, but occasionally moderately long or moderately short.

LEAF

Usually dorsiventral, but sub-centric in species of *Celtis*. **Hairs** including glandular and non-glandular types. (A) Non-glandular kinds mostly unicellular or bicellular, frequently calcified or silicified; furnished with calcified warts in species of *Aphananthe*, *Celtis*, *Gironniera*, *Trema*; occasionally with bodies resembling cystoliths attached to the lateral walls. See also under 'Cystoliths' on p. 1273. Special types of trichome include: (i) Long, narrow hairs in species of *Celtis* and *Zelkova*. (ii) Hairs with the broadest portion in the middle in *Ampelocera ruizii* Klotzsch. (iii) Hairs with thin walls and sometimes containing cystoliths, forming a felt-like covering on the lower surface of the leaf in certain species of *Trema*. (B) Glandular hairs, each with a uniseriate or unicellular stalk of variable length and a head composed of 1 or several cells, recorded in species of *Ampelocera*, *Aphananthe*, *Celtis*, *Gironniera*, *Holoptelea*, *Phyllostylon*, *Planera*, *Trema*, *Ulmus*. Glandular hairs exhibiting a considerable range of variation even within the limits of a genus. **Leaf teeth,** especially of young leaves, sometimes secreting mucilage. Strong **cuticular ridges** developed on the lower surface of the leaf in certain species of *Celtis* and *Ulmus*. **Epidermis** composed of cells with straight or sinuous anticlinal walls; papillose on the lower surface in species of *Celtis*; mucilaginous in all investigated species of *Ampelocera*, *Celtis*, *Chaetachme*, *Gironniera*, *Parasponia*, *Phyllostylon*, *Planera*, *Trema* (pro parte), *Ulmus*, *Zelkova*. Epidermis frequently 2-layered in species of *Aphananthe*, *Celtis*, *Gironniera*, *Holoptelea*, *Parasponia*, *Trema*. **Stomata** usually confined to the lower surface except sometimes in *Celtis* and *Trema*; statements in the literature concerning the adjacent cells somewhat vague, but subsidiary cells apparently absent or not well defined. **Mesophyll.** Palisade tissue consisting of 1 or more layers; lateral walls sometimes slightly sinuous in certain species of *Celtis*. Spongy tissue containing large lacunae in species of *Planera*, *Ulmus*, and *Zelkova*, but much denser in other members of the family. Palisade cells taller (sometimes 2-layered) in xerophytic than in mesophytic leaves of *Ulmus americana* Linn., according to Starr (2188).

Vascular bundles of the **veins** accompanied by sclerenchyma in *Aphananthe* (pro parte), *Celtis* (pro parte), *Gironniera*, *Planera*, *Ulmus*, *Zelkova*, or by a sheath of large parenchymatous cells devoid of chlorophyll in *Aphananthe* (pro parte), *Celtis* (pro parte), *Parasponia*, *Phyllostylon*, *Trema*; no sheath of either sclerenchyma or parenchyma present in a few species of *Ampelocera*, *Aphananthe*, *Celtis*, *Gironniera*, *Parasponia*, *Phyllostylon*, *Planera*, *Trema*, *Ulmus*. **Petiole** (Fig. 305 A, C, D, E), according to Solereder, supplied by a crescentic bundle in species of *Aphananthe*, *Celtis*, *Trema*, *Zelkova*; by a ring of xylem and phloem in species of *Chaetachme*, *Phyllostylon*, *Planera*, *Ulmus*, and by 3 separate bundles in *Gironniera*. Three bundles also recorded in the base of the petiole in species of *Celtis*, *Planera*, and *Ulmus*. Petiole, in transverse sections through the distal end of material examined at Kew, exhibiting a median, shallow, somewhat sinuous, crescentic vascular strand in *Celtis caucasica* Willd. and *C. occidentalis* Linn. (Fig. 305 A), and a cylindrical or almost closed vascular strand in species of *Planera* (Fig. 305 C), *Ulmus* (Fig. 305 D), and *Zelkova* (Fig. 305 E). No accessory bundles noted in the petiole. Xylem in the petiolar vascular strands including short, crowded, radial rows of vessels. **Mucilage cells** recorded in the mesophyll of *Celtis, Gironniera, Phyllostylon.* Cell walls of the epidermis, and, less frequently, of the mesophyll, sometimes calcified or silicified. Besides the bodies resembling **cystoliths,** mentioned above as occurring in association with the hairs, true cystoliths are also present in the epidermis and occasionally the mesophyll. Cystoliths in the upper epidermis, mostly associated with the hairs, seen by Satake (1997) only in *Celtis* and *Trema* amongst the Japanese genera he examined by the spodogram method. Solitary and clustered **crystals** occur either alone or together in different species; solitary types sometimes situated around the vascular bundles; clusters common in the mesophyll. Solitary and clustered types noted by Satake (1997) in Japanese species of *Aphananthe, Celtis,* and *Ulmus*; only solitary crystals observed by the same author in *Zelkova* and only clustered crystals in *Trema.*

AXIS

YOUNG STEM (Fig. 305 B)

Outermost part of the **cortex** sometimes silicified in *Celtis* and *Ulmus.* Stone cells noted in the cortex of *Zelkova.* **Cork** originating in the subepidermis; consisting of cells with wide lumina; containing stone cells in *Celtis.* A massive periderm present in *Ulmus suberosa* Michaux. **Pericycle** including a continuous or, at most, slightly interrupted ring of sclerenchyma in species of *Celtis, Planera,* and *Zelkova* examined at Kew; pericyclic sclerenchyma more definitely in the form of separate strands in *Ulmus.* Secondary **phloem** in *Celtis, Ulmus, Zelkova,* and probably other genera, including strands of fibres, or occasionally stratified into hard and soft portions (Fig. 305 B). **Xylem.** Primary rather clearly differentiated from the secondary xylem, the former having the vessels arranged in short radial rows. Secondary xylem in the form of a more or less continuous cylinder traversed only by fairly narrow rays in species of *Celtis, Planera, Ulmus* (Fig. 305 B), and *Zelkova* examined at Kew. Vessel perforations simple. **Pith** composed of thick-walled active cells in *Planera*; central portion consisting of rather large, empty cells with thin walls in *Celtis* and *Ulmus.* **Secretory cells** with mucilaginous contents widely distributed in the unlignified tissues of species of *Planera, Ulmus,* and *Zelkova,* but none seen in any of 3 species of *Celtis* available for examination. Groups of mucilage cells sometimes coalesce to form cavities in the cortex and pith of *Ulmus.* Large, often vertically elongated, mucilage cells recorded by Solereder in the secondary phloem of *Ulmus,* but varying in abundance in different species (see also Slippery Elm Bark under 'Economic Uses' on p. 1277).

Solitary and clustered **crystals** present in the cortex of species of *Celtis, Planera, Ulmus,* and *Zelkova* and in the phloem also in the same species of *Planera*; similar crystals also noted in the pith of *Celtis* and *Zelkova.* Solitary crystals enclosed in sclerotic cells in the pericycle also noted at Kew. Bodies resembling styloids recorded by Solereder in the region of the primary phloem of *Celtis.*

WOOD (Fig. 306)

Vessels typically medium-sized (mean tangential diameter 100–200 μ) in the diffuse-porous woods, but distinctly smaller (about 50 μ) in some species

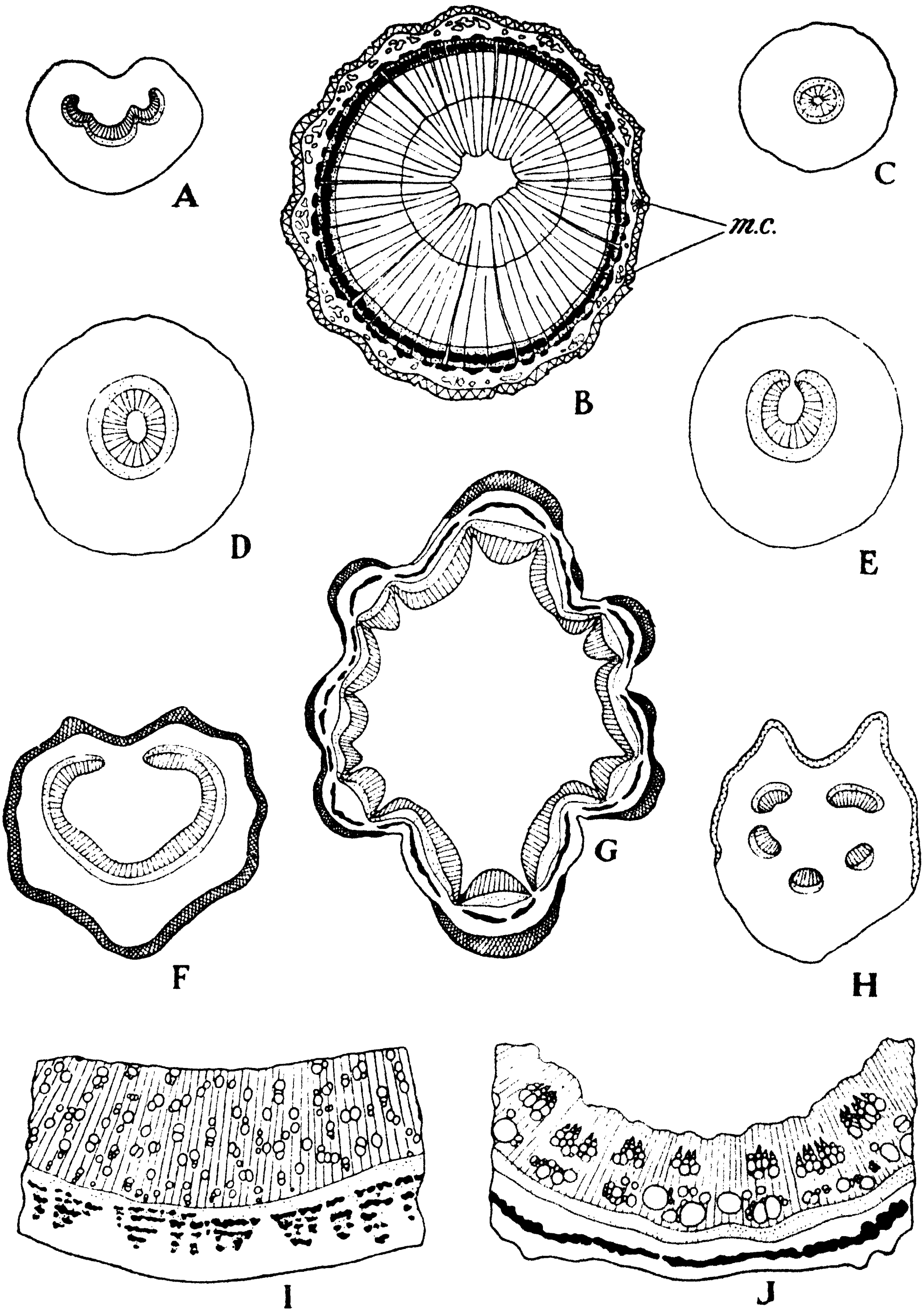


FIG. 305. *ULMACEAE*, A–E; *CANNABINACEAE*, F–J

A, ***Celtis occidentalis*** Linn. Petiole × 19. B, *Ulmus glabra* Huds. Stem × 15. C, ***Planera aquatica*** J. F. Gmel. Petiole × 19. D, *Ulmus americana* Linn. Petiole × 19. E, ***Zelkova carpinifolia*** Koch. Petiole × 19. F, *Cannabis sativa* Linn. Petiole × 13. G, *C. sativa* Linn. Young stem × 13. H, ***Humulus lupulus*** Linn. Petiole × 19. I, *Cannabis sativa* Linn. Old stem × 19. J, ***Humulus lupulus*** Linn. Stem × 19. (Fibres in I and J with cellulose walls.)

m.c. Mucilage cavities.

of *Ampelocera* and *Phyllostylon*; variable in arrangement, predominantly solitary in some species of *Aphananthe*, *Holoptelea*, and *Trema*, with numerous multiples of 4 or more cells giving a radial pattern in *Planera* (1886) and *Phyllostylon*, and in wavy, ulmiform tangential bands in *Celtis* p.p., *Ulmus* (Fig. 306 H), and *Zelkova*; mostly 5–12 per sq. mm. (apart from woods with an ulmiform or tangential pattern), fewer in some species of *Aphananthe*, *Celtis*, *Gironniera*, and *Trema*, 40 or more per sq. mm. in *Phyllostylon*; ring-porous in *Celtis* (some species), *Ulmus*, and *Zelkova* and semi-ring-porous in *Chaetoptelea* (1886); spiral thickening present in *Aphananthe aspera* Pl., *Celtis* (some species) (1886), *Planera* (1886), *Ulmus*, and *Zelkova*, and in the smallest vessels of *Chaetoptelea* (1886). Perforations simple; Solereder refers to scalariform plates with 1–6 bars near the primary wood in *Planera aquatica* Gmel. Intervascular pitting typically alternate, but Tippo (2261) notes opposite pitting in 3 species; usually medium-sized to moderately large, but small in some species of *Celtis* and *Gironniera*; pitting to ray and wood parenchyma typically including many large, elongated, and often simple pits, but such pits rare in *Ampelocera*, *Celtis*, *Holoptelea*, *Ulmus*, and *Zelkova*. Tyloses sometimes present, pitted in *Phyllostylon*, and, according to Gonggrijp (794), containing silica in *Gironniera* spp. Deposits of calcium carbonate characteristic of *Ampelocera* and *Phyllostylon* (1518, 1524, 1818) and reported also in some species of *Celtis* (1829), *Holoptelea* (1818), and *Ulmus* (1818). Mean member length 0·2–0·55 mm. **Parenchyma** varying in abundance and type, but usually essentially paratracheal; limited to narrow sheaths or a few cells round the vessels in *Celtis rhamnifolia* Presl., *Gironniera nervosa* Planch., *G. subaequalis* Planch., *Parasponia*, *Phyllostylon*, and *Trema* (Fig. 306 E), and round the ulmiform or tangential bands of vessels in *Celtis* p.p., *Ulmus*, and *Zelkova*; banded in the other genera or species (Fig. 306 A and D), the bands in some cases obviously confluent, in others suggesting broad apotracheal bands, except that the parenchyma tends to become aliform where less abundant locally; all types represented in different species of *Celtis*; in numerous uniseriate lines in *Planera* (1886); terminal bands sometimes present. Occasionally containing a few solitary crystals and, according to Gonggrijp (794), containing silica in *Gironniera* spp. Strands usually of 4 cells, but commonly of 2 cells in some species, and with some fusiform cells in *Ampelocera glabra* Kuhlmann (1524) and *Phyllostylon*. Storied in *Ampelocera*, *Holoptelea*, *Phyllostylon*, and *Zelkova* p.p. **Rays** usually up to 3–5 cells wide, but up to 6–12 cells in *Celtis*, *Chaetoptelea* (1886), *Gironniera* p.p., *Planera* (1886), *Ulmus*, and *Zelkova*; sometimes only 2, occasionally 3, cells wide in *Phyllostylon* and *Trema* (1886); typically less than 1 mm. high, but slightly higher in some species of *Celtis*, *Gironniera*, *Parasponia*, and *Zelkova*; uniseriates typically very few and low, but numerous and moderately high in *Celtis rendleana* G. Taylor, *Chaetachme*, and *Trema*; mostly 4–12 rays per mm., fewer than 4 per mm. in *Celtis* (in some species only) and *Zelkova*; most commonly heterogeneous (Kribs's Type II A) with 1–3 marginal rows of square to upright cells; more markedly heterogeneous (Kribs's Type I) in *Celtis rendleana*, *Chaetachme*, *Gironniera*, and *Trema* p.p.; homogeneous in *Ampelocera* (1518), *Chaetoptelea* (1886), *Holoptelea*, *Phyllostylon*, *Planera* (1886), and *Ulmus*, and, except for crystalliferous cells, in *Zelkova*; with sheath cells in some species of *Celtis*, *Parasponia*, and *Zelkova*; the procumbent cells often very narrow axially and tangentially (as seen in tangential section) in many species of *Celtis* (Fig. 306 c). Solitary crystals sometimes present; those of *Zelkova* large and occurring in swollen cells, particularly in the marginal rows. All the rays storied in *Holoptelea* and with the small rays storied in *Ampelocera*. **Fibres** typically with small simple pits, rather few and mostly on the radial walls; occasionally with very small bordered pits (2158, 2261), e.g. in *Planera*. Walls usually of medium thickness, but thick in some species of *Aphananthe*, *Gironniera*, *Phyllostylon*, *Trema*, and *Zelkova*; sometimes with a gelatinous layer. Containing silica

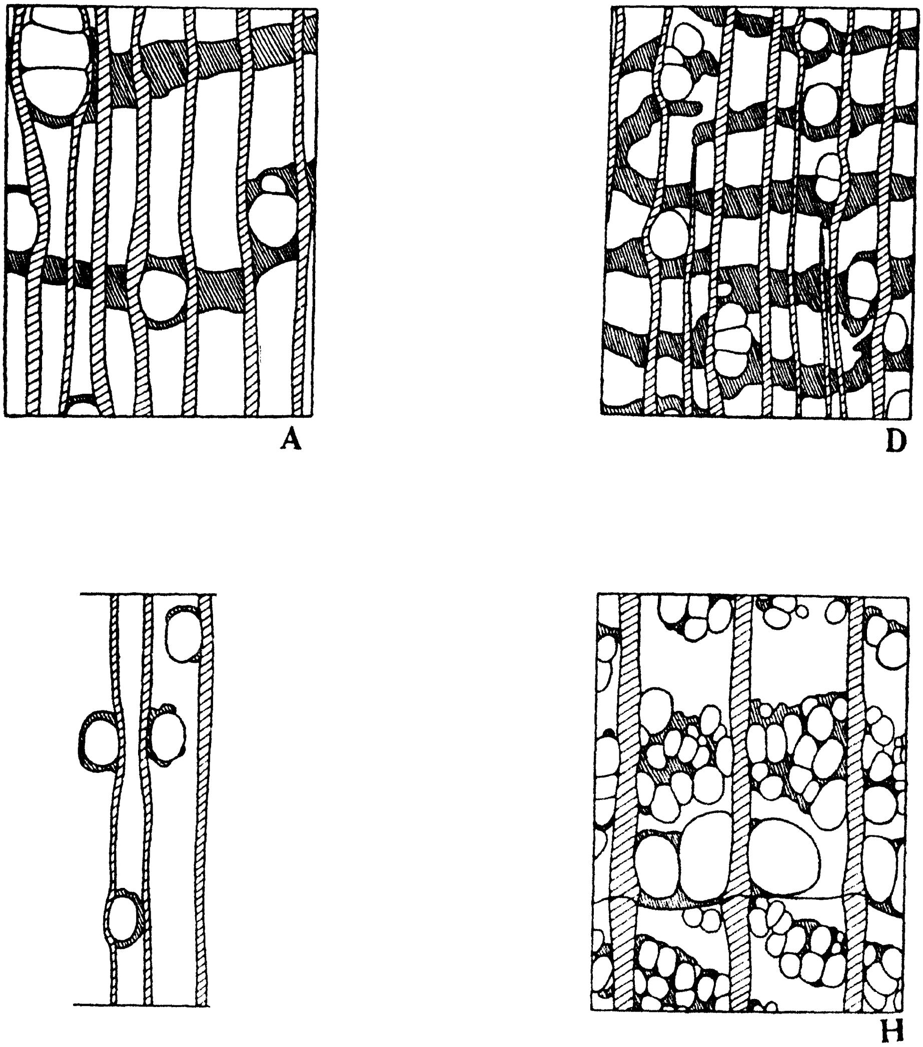


FIG. 306. *ULMACEAE*

A, *Holoptelea grandis* Mildbr. B, *H. grandis* Mildbr. C, *Celtis sinensis* Pers. D, *C. soyauxii* Engl. E, *Trema lamarckiana* Blume. F, *Chaetachme microcarpa* Rendle. G, *Ulmus procera* Salisb. H, *U. racemosa* Thomas.

crystals in *Parasponia* and *Ulmus* (794). Mean length 1·0–1·3 mm. in most genera, but slightly less in *Phyllostylon* (1884) and up to 1·9 mm. in *Zelkova* (100). **Intercellular canals** reported by den Berger and Bianchi (182) in the rays of *Gironniera.*

TAXONOMIC NOTES

(i) FROM GENERAL ANATOMY

The anatomical structure has points in common with that of the Cannabinaceae, Urticaceae, and Moraceae, which are generally accepted as closely related to the Ulmaceae.

(ii) FROM WOOD STRUCTURE

According to Tippo (2261) there are relatively more ring-porous species in the Ulmaceae than in the Moraceae and consequently a greater number of species with the advanced characters that are usually associated with the development of ring-porousness. Nevertheless, he considers that a comparison between the ring-porous species of each family, and similarly between the diffuse-porous species, shows the Moraceae to be more advanced than the Ulmaceae. The greater tendency to ring-porousness in the Ulmaceae may possibly be due to the temperate habitat of most of its members

Phyllostylon and *Planera* are both exceptional in several important characters. *Celtis* shows a remarkable amount of variation in its different species. Janssonius (1153, 1154) notes that *Gironniera subaequalis* Pl. and *G. cuspidata* Kurz show more marked differences than are usual within 1 genus; the former, with exclusively paratracheal parenchyma, he considers, resembles *Parasponia* and *Trema*; the latter is quite different, having abundant metatracheal parenchyma and other points of difference. He concludes that 'the two species cannot properly be included within a single genus'. It may be added that *Gironniera nervosa* Pl. appears to resemble the former species and *G. reticulata* Th. the latter.

ECONOMIC USES

Of the timbers produced by this family, far the most important are the various Elm woods furnished by species of *Ulmus* throughout the north temperate regions. Elm wood is noted for being tough, strong, and durable under water and, in addition, is attractive in appearance; it is used for various purposes, including shipbuilding, panelling, and furniture. Some species of *Aphananthe*, *Celtis*, and *Holoptelea* produce timbers that are used locally.

Slippery Elm Bark, derived from *Ulmus fulva* Michaux, a small tree from the centre and north of the U.S.A., is used in medicine because of its high mucilage content. The commercial bark, which has a reddish-brown outer and a tawny yellow inner surface, occurs in long pieces which are only about 3 mm. thick. Smoothed transverse surfaces exhibit alternating layers of phloem fibres and sieve tissue. The mucilage cells, which occur throughout the phloem, swell up quickly when moistened and are readily stained by Ruthenium red. Other microscopical features include the strongly thickened but only slightly lignified phloem fibres, surrounded by cells containing prisms of calcium oxalate; the numerous starch grains, mostly 3–5 but sometimes up to 25 μ in diameter.

Genera Described

(i) For General Anatomy

Ampelocera, Aphananthe, Celtis,* Chaetachme, Gironniera, Holoptelea, Parasponia, Phyllostylon, Planera,* Trema, Ulmus,* Zelkova.*

* Represented in the Kew slide collection.

(ii) For Wood Structure

Ampelocera, Aphananthe, Celtis, Chaetachme, (Chaetoptelea), Gironniera, Holoptelea, Parasponia, Phyllostylon, (Planera), Trema, Ulmus, Zelkova.

Literature

(i) *On General Anatomy*

Mohler **1544**, Puri **1762**, Satake **1997**, Starr **2188**, Varossieau **2324**.

(ii) *On Wood Structure*

Allsop and Misra **22**, Bailey and Tupper **100**, den Berger **179**, **182**, den Berger and Endert **183**, Besson **186**, Bienfait and Pfeiffer **197**, Brown, H. P. and Panshin **288**, **289**, Burgerstein **310**, **312**, Chalk *et al.* **364**, Chalk and Rendle **365**, Clarke **426**, Cox **490**, Dadswell **525**, Dallimore **535**, Gonggrijp **794**, Greguss **2522**, Hale **870**, Howard **1088**, Janssonius **1153**, **1154**, Jones **1191**, Kanehira **1206**, **1209**, Lodewick **1386**, Milanez **1518**, **1524**, Normand **1619**, Pearson and Brown **1679**, Pfeiffer, H. **1712**, Record **1781**, **1783**, **1809**, **1818**, **1824**, **1829**, **1843**, **1851**, **1884**, Record and Hess **1886**, Record and Mell **1894**, Schmidt **2040**, Scott **2075**, Stone **2203**, Tang **2230**, **2231**, Tippo **2261**, Uspensky **2317**, Varossieau **2324**, Williams **2430**, Yamabayashi **2478**.

252. PLATANACEAE

(Fig. 300 on p. 1250; Fig. 307 on p. 1280)

Summary

(i) General

A north temperate and sub-tropical family of trees belonging to the single genus *Platanus*. The **leaf** is isobilateral, and, when young, the exterior is covered with a dense woolly tomentum of **candelabra hairs,** but these are deciduous. The somewhat raised **stomata** are surrounded by rather numerous, unspecialized epidermal cells. The somewhat dilated base of the **petiole** encloses the axillary bud. It is partly for this reason that the petiolar vascular system is somewhat complex. The surface of the woody part of the axis becomes covered with characteristic **scale bark,** which originates in the manner described under 'Axis' on p. 1279. The **pericycle** of the axis contains a composite, continuous ring of sclerenchyma. The distal ends of the medullary rays where traversing the **phloem** become sclerosed at a very early stage, whilst the secondary phloem itself also becomes sclerosed rather later.

(ii) Wood

Vessels small, mostly solitary, perforation plates simple and scalariform, intervascular pitting usually opposite and pits to parenchyma similar, members of medium length. **Parenchyma** apotracheal, diffuse or in uniseriate bands, rather sparse. **Rays** usually up to 10–15 cells wide, with few or no uniseriates, homogeneous. **Fibres** with bordered pits, of medium length to moderately long.

LEAF

Isobilateral in all investigated species, with a single layer of palisade tissue towards both surfaces, but the component cells much shorter towards the lower than towards the upper side of the leaf. Young leaves covered with a dense woolly tomentum of deciduous **candelabra hairs,** which, according to Solereder, sometimes fall in sufficient quantities to cause inflammation of the mucous membranes in human beings. Less-branched and even uniseriate hairs also occur. Simple capitate glands, and branched hairs with glandular endings sometimes present as well. **Stomata** somewhat raised, surrounded by rather numerous cells exhibiting no special arrangement. **Hydathodes** present at the tips of the leaf teeth in *Platanus occidentalis* Linn. Vascular bundles of the larger **veins** surrounded by a ring of sclerenchyma in *P. occidentalis*; smaller strands vertically transcurrent by lignified tissue. Vascular system of the **petiole** (Fig. 307 G) of *P. occidentalis* very complex, partly owing to the presence of a conical cavity at the base. According to Solereder: 'A transverse section through the base of the petiole shows the central wide cavity enclosing the axillary bud, while the wall of the cavity contains a rather large number of vascular systems, some of which consist of rings of vascular bundles. At the apex of the petiole the fibrovascular system is composed of three arc-shaped or circular systems placed one above the other.' Petiole of *P. acerifolia* Willd. and *P. orientalis* Linn., when examined at Kew in transverse sections through the distal end, exhibited a somewhat interrupted, shallow, abaxial arc of bundles with incurved ends, accompanied by a complex adaxial system of vascular strands. All petiolar vascular strands supported by 'pericyclic' sclerenchyma. **Crystals** secreted in the form of clusters in association with the veins.

AXIS

YOUNG STEM (Fig. 307 F)

Cork arising in the outer part of the cortex in *P. occidentalis* Linn. and *P. orientalis* Linn.; component cells with thick walls and large lumina. Subsequent formation of **scale bark** described by Solereder as follows: 'Each scale of the bark is only a few cells thick and consists of thin-walled cells towards the outside and of cells with thick yellow walls on the inside. Exfoliation of the scale of bark is caused by a tearing of the thin-walled cells, while the thick-walled layer remains as a covering of the living tissues beneath until another layer of bark is subsequently cast off in the same way.' Primary **cortex** narrow; tending to be spongy. **Pericycle** with massive strands of fibres which become united by stone cells with large lumina to form a composite continuous ring of sclerenchyma. Primary **phloem** in the form of groups, separated from one another by the somewhat triangular, sclerosed, distal ends of the medullary rays. Secondary phloem becoming progressively more sclerosed with increase in age. **Xylem,** in transverse sections, appearing to be dissected into distinct segments by broad, lignified, primary medullary rays (Fig. 307 F); including very numerous, irregularly grouped and solitary, thin-walled vessels with simple perforations and scalariform perforation

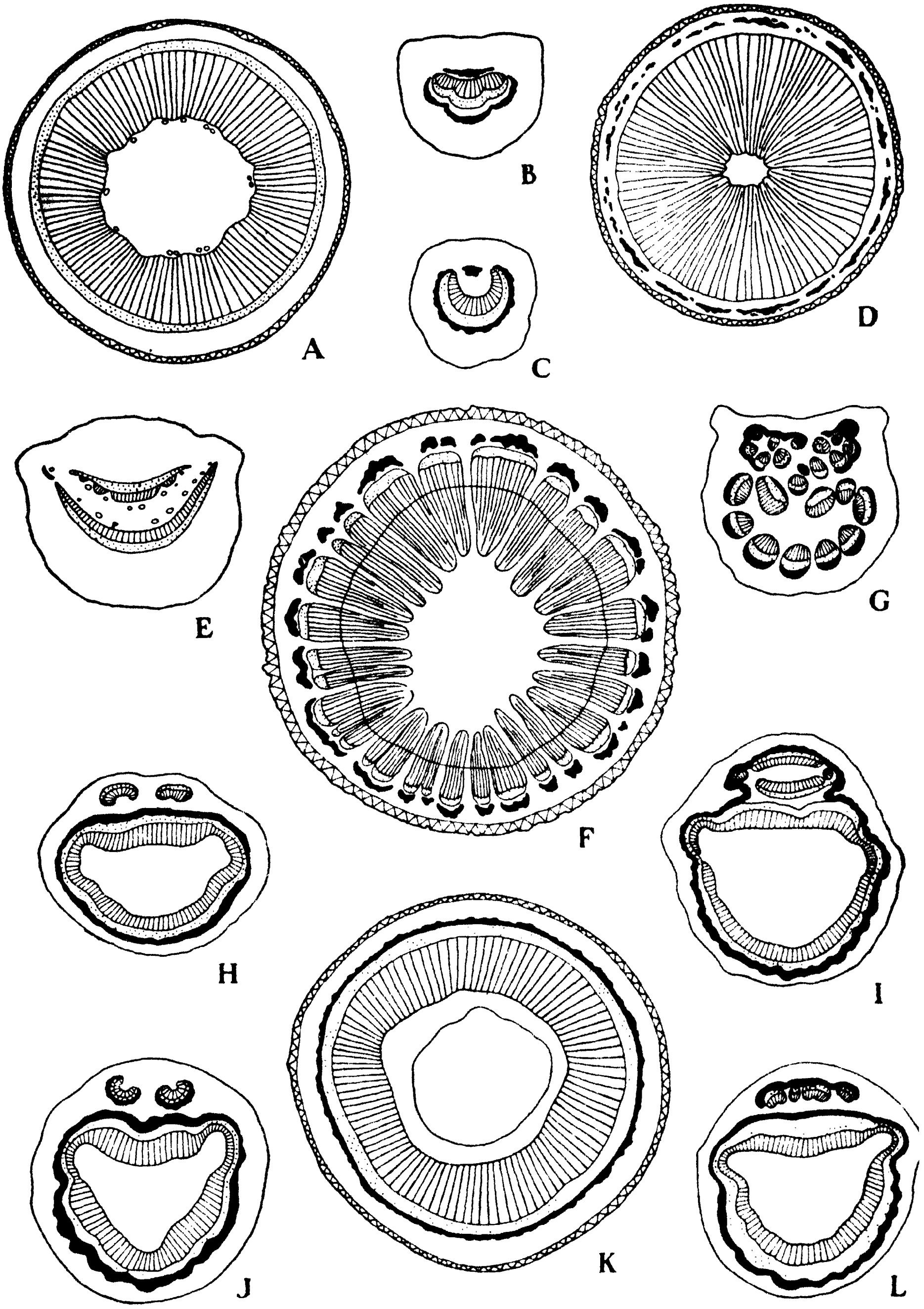


FIG. 307. *LEITNERIACEAE*, A and E; *MYRICACEAE*, B–D; *PLATANACEAE*, F–G; *JUGLANDACEAE*, H–L

A, ***Leitneria floridana*** Chapm. Stem × 11. B, ***Myrica gale*** Linn. Petiole × 29. C, ***Comptonia asplenifolia*** Ait. Petiole × 29. D, ***Myrica gale*** Linn. Stem × 8. E, ***Leitneria floridana*** Chapm. Petiole × 13. F, ***Platanus orientalis*** Linn. Stem × 19. G, ***P. orientalis*** Linn. Petiole × 19. H, ***Carya ovata*** Koch. Petiole × 8. I, ***Platycarya strobilacea*** S. et Z. Petiole × 14. J, ***Pterocarya hupehensis*** Skan. Petiole × 14. K, ***Juglans regia*** Linn. Stem × 7. L, ***J. regia*** Linn. Petiole × 8.

The stratification of the phloem in fig. A is not shown.

plates. **Pith** fairly broad, mainly composed of moderately thick-walled, simple-pitted, sometimes amyliferous cells, but slightly heterogeneous owing to the presence of a small proportion of cells with thicker walls and filled with amorphous contents. Periphery of pith appearing somewhat radiate owing to its being continuous with the enlarged proximal ends of the primary medullary rays.

Secretory cells with unidentified, amorphous contents noted in the cortex and pith, and smaller ones in the phloem. **Crystals** rather infrequent; when present occurring as solitary and clustered types, the distribution of each kind varying somewhat in different species. The following types noted at Kew in *P. acerifolia* Willd. Occasional solitary, cubical or prismatic crystals in cells at the outer periphery of the pericyclic fibres and in some of the sclerosed cells at the distal ends of the rays; infrequent clusters present in some of the unsclerosed cells near the distal ends of the rays, as well as in the inner part of the primary cortex and peripheral part of the pith.

WOOD (Fig. 300 A–B)

Vessels moderately small (50–100 μ mean tangential diameter); solitary and in radial to tangential pairs and threes; usually about 70 per sq. mm.; tending to be more numerous at the beginning of the ring. Perforation plates simple and scalariform, the latter with fewer than 20 bars and either predominant or scarce. Intervascular pitting typically opposite, but occasionally alternate (299) or almost scalariform; pits to parenchyma similar. Thin-walled tyloses often present. Mean member length 0·5–0·8 mm. **Parenchyma** apotracheal, usually as scattered cells, but sometimes in distinct uniseriate bands from ray to ray. Strands of 4–8 cells. **Rays** up to 8–20 cells wide; commonly 2–3 mm. high, but sometimes dissected into shorter units, e.g. in *P. acerifolia* Willd.; with very few or no uniseriates; about 2 rays per mm.; homogeneous (Kribs's Type II); usually with abundant gummy contents and often with numerous chambered crystals in *P. orientalis* L. **Fibres** with numerous bordered pits in all walls. Walls moderately thick. Mean length about 1·6 mm.

TAXONOMIC NOTES

Tippo (2261) considers that the wood anatomy of the Platanaceae resembles that of the Hamamelidaceae in many ways, but is on a higher plane of specialization than the latter and the Buxaceae, Myrothamnaceae, and Stachyuraceae.

ECONOMIC USES

Plane trees are commonly cultivated for ornamental purposes and for their beautifully figured timber. The London Plane is *P. acerifolia* Willd., which is believed to be a hybrid between *P. occidentalis* Linn. and *P. orientalis* Linn.

GENUS DESCRIBED

Platanus.*

* Represented in the Kew slide collection.

LITERATURE

(i) *On General Anatomy*

Starr **2188**.

(ii) *On Wood Structure*

Baird 102, Brown and Panshin 288, 289, Brush 299, Chalk and Rendle 365, Dadswell and Record 533, Greguss 2522, Hale 870, Jones 1191, Nicoloff 1593, Record 1783, 1843, 1851, Record and Hess 1886, Record and Mell 1894, Stone 2203, Tippo 2261, Tupper 2295.

253. LEITNERIACEAE

(FIG. 307 on p. 1280)

SUMMARY

(i) GENERAL

A family of shrubs belonging to the single genus *Leitneria.* The following description refers to the sole species *L. floridana* Chapm. which is confined to certain parts of the U.S.A. The most noteworthy feature is the presence of **secretory canals** with yellow resinous contents, situated at the margin of the pith in the axis, and extending, in association with the vascular bundles, into the finest veins of the leaf. The few other characters which have been recorded can best be considered under the organs in which they occur.

(ii) WOOD

Vessels small and in diagonal or zigzag rows, semi-ring-porous, with spiral thickening, perforations simple, intervascular pitting scalariform to opposite. **Parenchyma** scanty paratracheal to vasicentric and terminal. **Rays** exclusively uniseriate. **Fibres** with extremely small pits.

LEAF

Dorsiventral. **Hairs** of 2 kinds. (i) Simple, uniseriate, often with bulbous bases; occasionally arranged in pairs with their bases sunk in the epidermis. (ii) Club-shaped glands, with biseriate stalks, not very well demarcated from the multicellular heads. **Stomata** not depressed. **Petiole** (Fig. 307 E), in transverse sections through the distal end, exhibiting an abaxial crescent of vascular tissue with an additional, slightly concave strand between and almost connecting the ends of the crescent. Three vascular bundles said to occur in the base of the petiole. Petiolar xylem including small vessels in short, crowded, radial rows. **Secretory canals** present in the 'medullary' region of the petiole, and also accompanying the vascular bundles into the finest veins. Clustered **crystals** abundant in several layers of cells below the upper epidermis of the lamina.

AXIS

YOUNG STEM (Fig. 307 A)

Surface of young stem covered with fairly long, moderately thick-walled, uniseriate **hairs** with fine transverse septa. **Cork** originating immediately below the epidermis. Primary **cortex** mainly composed of thin-walled parenchyma, but outer part tending to be collenchymatous. **Pericycle** including distinct strands of rather thin-walled fibres when young, but fibre strands becoming compressed and inconspicuous in consequence of secondary thickening. **Phloem** appearing as distinct groups when young but, when somewhat older, traversed only by uniseriate medullary rays, the distal ends of the latter sometimes tending to be triangular. Enlarged distal ends of the rays not very obvious in material examined at Kew. Secondary phloem including concentric, tangentially compressed layers of thin-walled fibres, the fibre cells having wider lumina than those of the narrow, intervening layers of soft tissue. **Xylem.** Vessels in the primary xylem mostly in radial rows. Secondary xylem forming a continuous cylinder traversed by narrow, uniseriate or occasionally biseriate rays; vessels mostly arranged in tangential or oblique rows of up to about 20 members, but a few solitary vessels noted as well. Individual vessel members, in material examined at Kew, up to about 60 μ in radial diameter, but larger ones up to 90 μ in diameter recorded by Solereder. Vessels with rather large, horizontal, bordered pits in the lateral walls; vessel-ray pits described by Solereder as large and simple; only simple, usually slightly oblique perforation plates observed. Ground-tissue of the xylem chiefly composed of thin-walled fibres with wide lumina and simple pits. **Pith** chiefly consisting of thin-walled parenchyma, but peripheral part composed of much smaller cells. Cluster **crystals** abundant in a definite zone of cells in the primary cortex; a few also noted in the peripheral part of the pith. **Secretory elements.** Twelve to 24 secretory canals, lined with epithelium, present in the peripheral part of the pith, close to the primary xylem groups; contents described by Solereder as a yellow, brittle, resinous material. Tanniniferous cells present in the cortex.

WOOD[1]

Vessels 'in early wood in part small or occasionally medium-sized in association with very small ones and arranged in uniseriate arcs 2 to 6 pores long or in interrupted concentric rows; other pores very small to minute, rather few, and arranged in scattered radial, diagonal, or zigzag rows or patches often originating at one end of the larger pore arcs and extending across the growth ring'. Semi-ring-porous and with spiral thickening at least in the smaller vessels. Perforations simple. Intervascular pitting opposite in the smaller, intermediate to scalariform in the larger vessels; pits to ray or wood parenchyma similar to the latter. **Parenchyma** paratracheal, scanty to vasicentric, and in fine terminal bands. **Rays** exclusively uniseriate and composed of rather large, oblong to square cells. **Fibres** with numerous extremely small pits and very thin walls.

TAXONOMIC NOTES

Solereder has pointed out that the secretory canals and the stratified phloem in the axis recall the structure of the Dipterocarpaceae, although *Leitneria* differs from many members of this last family in having no cortical vascular bundles.

GENUS DESCRIBED

Leitneria.*

* Represented in the Kew slide collection.

LITERATURE

On Wood Structure

Record 1783, 1843, 1851, Record and Hess 1886.

---

[1] Based entirely on the description given by Record and Hess (1886).

254. *JUGLANDACEAE*

(Fig. 307 on p. 1280; Fig. 308 on p. 1286)

SUMMARY

(i) GENERAL

A family of trees, chiefly from north temperate regions, but also occurring on mountains in the northern tropics. The most characteristic feature of the leaf is the occurrence of shortly stalked, peltate **glands** which secrete resinous material. The ranunculaceous **stomata,** which, according to Solereder, are frequently of 2 distinct sizes in a single leaf, are confined to the lower surface. **Crystals** are mostly clustered, and sometimes very large. The vascular system of the **petiole,** as seen in transverse sections through the distal end, appears as a main cylindrical strand accompanied by others on the adaxial side. In the stem, the **pericycle** always contains sclerenchymatous elements, but a composite continuous ring is known only in *Juglans*. The **pith** is septate in *Juglans* and *Pterocarya* but not in the other genera.

(ii) WOOD

Vessels typically few and medium-sized to large, often tending to have an oblique pattern, often ring-porous, perforations usually simple, but a few scalariform plates present in 2 genera, intervascular pitting alternate and moderately large, pits to parenchyma usually similar, but larger and elongated in a few species, members of medium length. **Parenchyma** either predominantly apotracheal, as short uniseriate bands to continuous bands 2 or 3 cells wide, or mainly as broken bands that are intermediate between apotracheal and paratracheal. **Rays** 2–7, usually 2–4, cells wide, heterogeneous, with several marginal rows, to almost homogeneous. **Fibres** with bordered pits, of medium length. Spirally thickened **vascular tracheids** present in *Platycarya.*

LEAF

Generally dorsiventral, with 1 or 2 layers of palisade cells; rarely tending to be isobilateral, e.g. in *Engelhardtia serrata* Bl. **Hairs** often more numerous on young than on old leaves; including several distinct glandular and non-glandular types. Peltate **glands,** with short unicellular or uniseriate stalks composed of cells with yellow walls, constitute one of the most constant and characteristic features. Stalked, capitate glands also occur in *Juglans*, but none recorded in the other genera. The glandular hairs secrete resinous material. Simple, unicellular hairs also frequent, some of those in certain species of *Pterocarya* provided with pointed apices and bulbous bases, others in the same genus being somewhat curly and provided with thick walls. Tufts of stiff, unicellular, sclerenchymatous trichomes also common, sometimes appearing stellate.

The following features of the hairs and glands enable genera to be identified, according to Nagel (1578).

(i) Simple, unicellular or uniseriate hairs consisting of 1 to several cells.

(*a*) Solitary, unicellular hairs, swollen at the base, provided with fairly thick walls and surrounded by a circle of 8 cells—*Platycarya.*

(*b*) Hairs similar to those in (*a*) but surrounded by 6–8 cells. Female flowers and fruits provided with unicellular, thick-walled, warty, bristles—*Engelhardtia.*

(*c*) Solitary, unicellular hairs accompanied by tufted hairs, each of the latter consisting of 2–4 unicellular components—*Carya, Pterocarya.*
Tufted hairs similar but consisting of 5–7 components—*Juglans.*

(ii) Capitate glands.

Small, capitate glands with short, 2-celled stalks and 4-celled heads—*Juglans.*

(iii) Glandular, peltate scales.

(*a*) All glands of one type.
66·6–92·5 μ in diameter—*Platycarya.*
92·5–203·5 μ in diameter—*Engelhardtia.*
66·6–81 μ in diameter—*Pterocarya,* section *Cycloptera.*

(*b*) Glands of 2 distinct sizes.
Larger 74–111 μ in diameter. Smaller 29·6–37 μ—*Pterocarya,* sections *Stenoptera* and *Platyptera.*
Larger 74–185 μ in diameter. Smaller 37 μ—*Juglans.*
Larger 81·4–222 μ in diameter. Smaller 44–111 μ—*Carya.*

For further details concerning hairs see Parmentier (1655) and Nagel (1578).

Stomata said by Solereder to be of 2 distinct sizes in a single leaf; always confined to the lower surface; ranunculaceous. **Midrib** including a central, but sometimes dissected, cylinder of xylem, surrounded by groups of phloem. Small **veins** of the leaflet often containing a single vascular bundle. Basal portion of the **petiole** of *Carya, Engelhardtia, Juglans, Platycarya, Pterocarya* described by Solereder as containing a closed vascular system, appearing triangular in outline in transverse sections. Variously shaped and orientated, additional, vascular strands visible on the adaxial side of the main cylinder in transverse sections through the distal end of petioles of *Carya* (Fig. 307 H), *Juglans* (Fig. 307 L), *Platycarya* (Fig. 307 I), and *Pterocarya* (Fig. 307 J) examined at Kew. The additional strands arise as branches from the main vascular strand lower down in the petiole. Vascular system of the petiole sheathed by sclerenchyma in the 'pericyclic' region. **Crystals** mostly clustered, but solitary types recorded (Solereder, Lutz 1404, Holm 1004), especially near the veins, in species of *Carya, Juglans, Platycarya, Pterocarya.* Especially large cluster crystals common in the uppermost layer of palisade cells, sometimes appearing as transparent spots in species of *Carya, Juglans, Platycarya.* Cluster crystals in the corresponding position in *Engelhardtia* much smaller (Nagel 1578). Cells normally occupied by crystals found empty in *E. lepidota* Schlecht. and *E. rigida* Bl. **Oil drops** recorded by Holm (1004) in the upper epidermis of *Carya.*

Foster (692, 693) has studied the **developmental anatomy** of foliage leaves and cataphylls in *Carya.* He concluded that 'the fundamental architecture of the cataphyll is that of a simple foliar organ possessing an axial region flanked by lateral often asymmetrical wings'. The development and vascular organization of the foliar organs of *Carya cordiformis* K. Koch. has also been studied by Langdon (1318).

Axis

Young Stem (Fig. 307 k)

Cork arising in the sub-epidermis; component cells thin-walled with rather wide lumina, or with thickened walls and flattened. Primary **cortex** frequently collenchymatous. **Pericycle** always containing separate strands of fibres in *Carya*, *Platycarya*, and *Pterocarya*, but united by stone cells to form a composite, almost or quite continuous ring in species of *Juglans*. **Phloem**, in transverse sections, generally appearing as a more or less continuous cylinder apart from the narrow medullary rays, but a few of the rays seen to have enlarged, triangular, distal ends in species of *Carya* and *Juglans* examined at Kew, and similar structure recorded by Solereder in *Engelhardtia*. Well-developed lateral sieve plates, accompanied by callus similar to that on the

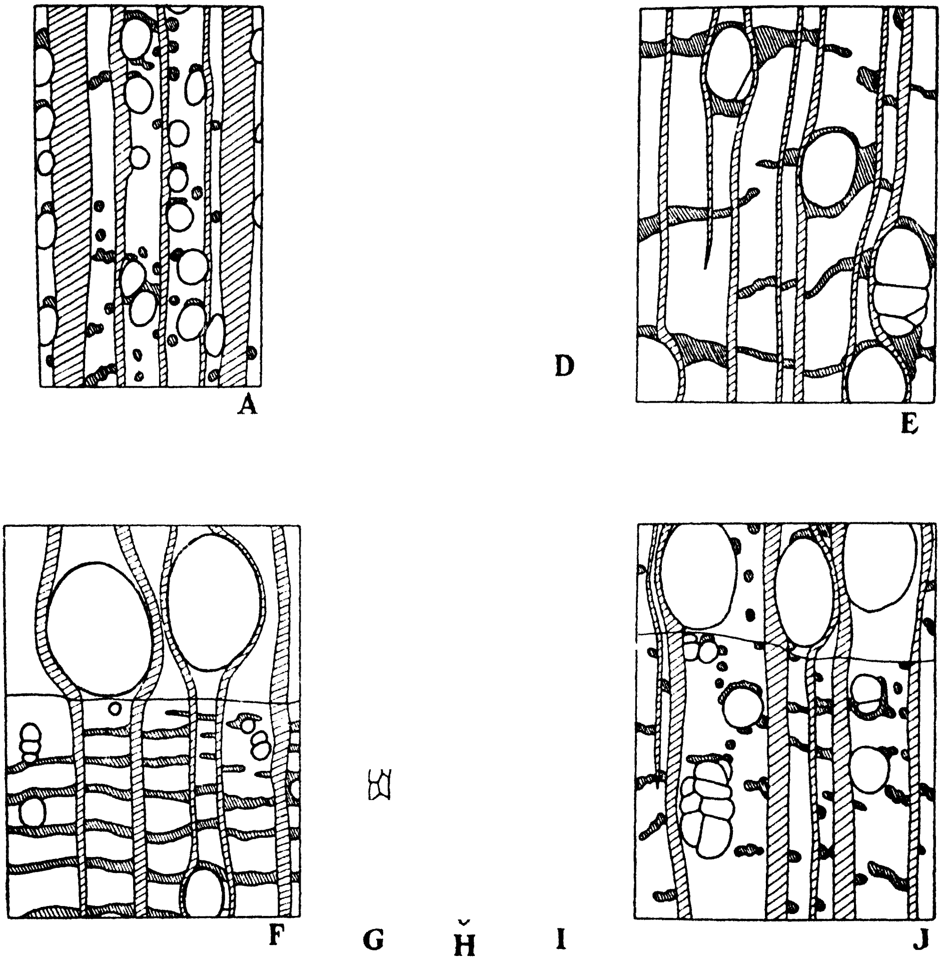


Fig. 308. *MYRICACEAE*, A–C; *JUGLANDACEAE*, D–J

A, *Myrica nagi* Thunb. B, *M. cerifera* Linn. C, *M. nagi* Thunb. D, *Pterocarya rhoifolia* S. et Z. E, *Engelhardtia wallichiana* Lindl. F, *Carya tomentosa* Nutt. G, *Engelhardtia nudiflora* Hook. f. H, *Carya tomentosa* Nutt. I, *Juglans regia* Linn. J, *J. regia* Linn.

end walls, noted by Hemenway (947) in the sieve tubes of *Carya*, *Juglans*, and *Pterocarya*. **Xylem** in the form of a continuous cylinder traversed by narrow medullary rays; only simple perforations in the vessels noted in the species examined at Kew. See also under 'Wood'. **Pith** in *Juglans* and *Pterocarya* septate by diaphragms composed of cells which are empty or contain clustered crystals. Peripheral part of the pith composed of cells with thick walls; central part consisting of thin or thick walls in different species.

Clustered **crystals** usually abundant in the cortex, unlignified portions of the phloem, and in the pith; those in the cortex of *Pterocarya rhoifolia* Sieb. et Zucc. said to be sufficiently numerous to be visible to the naked eye. Solitary crystals less numerous, but recorded or observed in the unsclerosed parts of the phloem in *Carya*, *Engelhardtia*, and *Juglans*, and also in the cortex of *Carya* and *Juglans*. **Secretory cells** with unidentified contents conspicuous and abundant in the cortex, phloem, medullary rays, and pith of species of *Carya*, *Juglans*, and *Pterocarya* examined at Kew, and in all of these tissues except the pith in *Platycarya strobilacea* Sieb. et Zucc.

WOOD (Fig. 308 D–J)

Vessels usually medium-sized (100–200 μ mean tangential diameter) or slightly larger; mostly solitary, though with some small multiples and clusters, and with moderately numerous multiples of up to 4 cells in some species of *Engelhardtia* and *Platycarya*; sometimes in loose oblique lines in *Engelhardtia* and in distinct oblique lines or flames in *Platycarya*; usually about 5 per sq. mm., sometimes not more than 2 per sq. mm. in *Engelhardtia*; ring-porous in *Carya*, *Juglans* p.p., and *Platycarya*, and tending to be ring-porous in *Pterocarya paliurus* Bat. (939); with spiral thickening in the small vessels of *Platycarya*. Perforations simple or simple and scalariform, some scalariform plates, usually with few bars, occurring in *Alfaroa* and *Engelhardtia*; Heimsch and Wetmore (939) state that some scalariform plates are present in all the species of *Engelhardtia*, but they appear to be so few in some species as to be lacking from individual sections. Intervascular pitting alternate and moderately large; pits to parenchyma usually similar, but with some elongated pits in *Alfaroa* and some species of *Engelhardtia*. Thin-walled tyloses common in almost all the species (Tippo 2261). Mean member length 0·4–0·9 mm., longest (sometimes up to 0·8 or 0·9 mm.) in *Alfaroa* and *Engelhardtia* (939). **Parenchyma** typically apotracheal, as scattered cells, short uniseriate bands (Fig. 308 J) or continuous bands 1–3 cells wide, often with a little paratracheal parenchyma in addition; continuous bands characteristic of *Alfaroa*, *Carya* (Fig. 308 F), *Engelhardtia* p.p., and *Pterocarya*; the species and varieties of *Engelhardtia* differ considerably, e.g. *E. spicata* Bl., according to Heimsch and Wetmore, has mainly diffuse parenchyma, while that of *E. spicata* Bl. var. *acerifolia* Koord. et Valet. is mostly in continuous apotracheal bands; in most of the other species the bands are less continuous and tend to be distinctly associated with the vessels (Fig. 308 E), as in *E. formosana* Hayeta and *E. wallichiana* Ridl., and might be considered as aliform and confluent; Heimsch and Wetmore note a similar, though less marked, association of the parenchyma bands with the vessels in some species of *Juglans*, e.g. *J. cinerea* L. and *J. colombianensis* Dode. Terminal bands reported (939) in all the species of *Engelhardtia* and *Juglans* that have growth rings. Crystals often present in

Engelhardtia and *Juglans*; Kribs (1284) draws attention to 'very large barrel-shaped wood parenchyma cells each containing elongated rhombohedral crystals of calcium oxalate' as characteristic of *Carya tonkinensis* H. Lecomte. Strands usually of 8 cells. **Rays** typically up to 2–4 cells wide, but sometimes 5–7 cells in *Juglans*; less than 1 mm. high; uniseriates moderately numerous, the cells tending to be all upright in *Alfaroa*, all square, or mixed square and procumbent, in *Engelhardtia* and *Platycarya*, and all procumbent to almost square in *Carya*, *Juglans*, and *Pterocarya*; 6–13 rays per mm.; heterogeneous (Kribs's Types I, in *Alfaroa*, and II A and B), with 4 or more, and sometimes more than 10, marginal rows of square to upright cells in *Alfaroa*, *Carya tonkinensis* H. Lecomte (Kribs 1284), *Engelhardtia*, and *Platycarya*; almost homogeneous (Kribs's Type I) in some species of *Carya*, *Juglans*, and *Pterocarya*; these genera commonly have numerous uniseriate marginal rows of cells that are barely distinguishable in tangential section from the cells of the multiseriate parts, though distinct in radial section as square to barely procumbent cells (Fig. 308 H and I). Sometimes containing crystals, which, according to Solereder, in *Carya* and *Engelhardtia* are single or clustered and are contained in ellipsoidal and swollen, or in transversely septate cells, and which are rather large in *Platycarya*. **Fibres** typically with bordered pits, but the pits very small and apparently simple in *Carya*, though Heimsch and Wetmore refer to them as having minute borders; pits almost entirely limited to the radial walls. Kanehira (1206) reports septate fibres in *Juglans formosana* Hay., but none was observed in the single specimen available to the author. Walls usually of medium thickness, often thick in *Carya* and very thin in *Pterocarya rhoifolia* Sieb. et Zucc.; some fibres with gelatinous layers reported (939) to be present in each genus. Mean length 1·1–1·5 mm. **Vascular tracheids** present in *Platycarya*; with spiral thickening.

ROOT

Pentarch structure recorded by Holm (1004) in *Carya*.

ECOLOGICAL ANATOMY

Some particulars concerning the physiological anatomy of various members of the family have been recorded by Nagel (1578). Small microscopical differences between leaves of xerophytic and mesophytic specimens of *Juglans cinerea* Linn. have been noted by Starr (2188). These include, in the xerophytic form, taller palisade tissue, often composed of 2 layers of cells, more numerous vessels in the xylem of the midrib and a more pubescent upper epidermis composed of smaller cells.

TAXONOMIC AND PHYLOGENETIC NOTES

(i) FROM GENERAL ANATOMY

The Juglandaceae are commonly regarded as a primitive family. Hemenway (947) has pointed out that the occurrence of sieve tubes with lateral sieve areas supports this contention, since this type of structure recalls that of the Gymnosperms.

The affinities of the family have been much discussed, and the various views which have been expressed on this subject have been summarized by Parmentier (1655) and Nagel (1578). Both authors conclude that the affinities of the Juglandaceae lie with those of the Cupuliferae, whilst there is little evidence to support any relationship with the Anacardiaceae or Julianiaceae. Nagel contrasts the anatomical differences between the Juglandaceae and Julianiaceae point by point.

In Parmentier's opinion the Juglandaceae are most nearly related to the Betulaceae and Fagaceae. Except for species of *Carpinus*, the Betulaceae and Fagaceae resemble the Juglandaceae in having the same type of stoma, similar unicellular hairs, whilst clustered hairs occur in *Fagus* as well as in some of the Juglandaceae, and there are also similarities in the glandular hairs of various genera. Specially large crystals of calcium oxalate occur in the palisade tissue of *Carpinus*, *Corylus*, and *Ostrya* as well as in the corresponding position in the Juglandaceae. In the stem the superficial cork, the occurrence of stone cells between the strands of pericyclic fibres, and the presence of fibres in the phloem serve to connect the Juglandaceae with the Cupuliferae, but here it should be noted that these resemblances are also common to other wholly unrelated families. Parmentier also pointed out that there are anatomical similarities between the Juglandaceae and Myricaceae, but he found marked differences between the Juglandaceae and the Balanopsidaceae, Burseraceae, Leitneriaceae, Moraceae, Salicaceae, Ulmaceae, and Urticaceae. Thus the Salicaceae usually have rubiaceous stomata and lack glandular hairs on the leaf. The Leitneriaceae differ from the Juglandaceae particularly in possessing secretory canals, whilst similar structures also occur in the Anacardiaceae and Burseraceae. The possession of laticiferous canals or similar tubes containing other materials also serves to distinguish many of the Moraceae and Urticaceae from the Juglandaceae.

(ii) From Wood Structure

Heimsch and Wetmore (939) point out that many anatomical characters are constant throughout the family, and Kribs (1282) also regards this as a 'natural' family. Kribs maintains that there are only 4 distinct genera, namely, *Carya*, *Platycarya*, *Juglans*, and *Engelhardtia*, and considers that *Pterocarya* belongs to the division of *Juglans* of which *J. cinerea* may be considered the type, and *Alfaroa* to the *Oreomunnea* section of *Engelhardtia*. The similarity between *Pterocarya* and the soft-wooded species of *Juglans* is confirmed by Heimsch and Wetmore, who state that the resemblance extends even to the primary wood.

According to Heimsch and Wetmore, *Alfaroa*, with its longer vessel members, more numerous scalariform perforation plates, and markedly heterogeneous rays, is rather primitive. *Engelhardtia*, although on the average more specialized anatomically than *Alfaroa*, has many of its primitive characters. *Pterocarya* and *Juglans* have reached a somewhat higher degree of specialization. The wood of *Platycarya* is much more highly specialized than is consistent with its primitive inflorescence. *Carya* has attained a level of structural organization not found in any other genus of the family.

Heimsch and Wetmore failed to find in the genera with several species any anatomical support for the taxonomic arrangement of the species. Their work on the anatomy of the wood is in striking accord with that of Manning[1] on the inflorescence, except in the case of *Platycarya*.

Tippo (2261) regards the Juglandaceae as more highly specialized anatomically than the Fagaceae, though he found the vessel members longer[2] and the ray type lower. He also considers the Juglandaceae more highly specialized than the Casuarinaceae, though here too he notes that the members are slightly longer in the Juglandaceae, the ray type lower, and the end-walls of the vessel members more oblique.

Heimsch (938) states that the Juglandaceae 'can hardly be conceived as stemming in the Anacardiaceae' and considers that if any collateral relationship between these families does exist, it must be a very remote one.

ECONOMIC USES

Two very important groups of timbers are produced by this family, the Walnuts, *Juglans* spp., and the Hickories, *Carya* spp. The two best-known species of Walnut are *Juglans regia* Linn., from Europe and Asia, and the North American Black Walnut, *J. nigra* Linn. Walnut is one of the world's finest cabinet woods, and is very decorative either in the solid or as veneer; veneers of walnut burrs are very highly prized. In addition to being attractive in appearance walnut is unusually tough and strong for its weight and is preferred above all other woods for gun-stocks. Hickory is exceptionally tough and elastic and is unrivalled for a number of special uses demanding these properties, e.g. for tool handles and sporting goods, such as skis and wooden golf club shafts.

Many of the Juglandaceae yield edible nuts, the most familiar in Europe being the Walnut (*Juglans regia* Linn.). Others such as the Pecan (*Carya pecan* Engl. et Graeb.) are cultivated in the U.S.A., &c.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Carya,* Engelhardtia, Juglans,* Platycarya,* Pterocarya.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Alfaroa, Carya, Engelhardtia, Juglans, Platycarya, Pterocarya.

LITERATURE

(i) *On General Anatomy*

Davy **552**, Foster **692**, **693**, Hemenway **947**, Holm **1004**, **1074**, Langdon **1318**, Lutz **1404**, Manning **1432**, Nagel **1578**, Parmentier **1655**, Starr **2188**, Withner **2449**.

(ii) *On Wood Structure*

Beekman **167**, den Berger **179**, den Berger and Endert **183**, Bienfait and Pfeiffer **197**, Brown, H. P. and Panshin **288**, **289**, Burgerstein **312**, Chalk and Rendle **365**, Chowdhury **411**, Desch **574**, Greguss **2522**, Hale **870**, Heimsch **938**, Heimsch and Wetmore **939**, Howard **1088**, Janssonius **1154**, Jones **1191**, Kanehira **1206**, **1209**, Kribs **1282**, **1284**, Lecomte **1331**, **1334**, Pearson and Brown **1679**, Record **1783**, **1818**, **1825**, **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**, Stone **2203**, Tang **2230**, **2231**, Tippo **2261**, Williams **2430**, Yamabayashi **2478**.

[1] Manning, E. W. 'The morphology of the flowers of the Juglandaceae. I. The inflorescence', *Amer. J. Bot.* **25**, 407–19; 1938. 'The types of stigmas in the Juglandaceae', ibid., **25**, 55; 1938.

[2] Figures available to the author suggest that there is no significant difference in member length between these two families.

255. MYRICACEAE

(FIG. 307 on p. 1280; FIG. 308 on p. 1286)

SUMMARY

(i) GENERAL

Aromatic trees or shrubs which are widely distributed in temperate regions. They usually bear **root tubercles** containing nitrogen-fixing bacteria. Their aromatic nature is caused by waxy material which is secreted from the leaves by characteristic peltate **glands.** Uniseriate glandular **hairs** also occur, and, in some species, certain of the epidermal cells with thin, outwardly arched walls also have a secretory function. The ranunculaceous **stomata** occur only on the lower surface of the leaf. In the stem, **cork** arises superficially, and the **pericycle** contains fibres and stone cells arranged in a continuous or interrupted ring. Both solitary and clustered **crystals** occur.

(ii) WOOD

Vessels small, usually exclusively solitary, sometimes tending to be ring-porous, perforation plates exclusively scalariform or scalariform and simple, intervascular pitting intermediate to alternate, pits to parenchyma round, members of medium length, occasionally moderately long. **Parenchyma** apotracheal, diffuse. **Rays** exclusively uniseriate or up to 4–8 cells wide, heterogeneous. **Fibres** with distinctly bordered pits, of medium length, occasionally moderately long.

LEAF

Nearly always dorsiventral, with 1 to several layers of palisade cells; almost isobilateral in *Myrica gale* Linn. owing to the palisade-like nature of the lowest layer of spongy tissue. Leaf surface, in nearly all species, bearing large, peltate **glands,** with uniseriate or biseriate, partly depressed stalks. In *M. gale* and other species, isolated epidermal cells become filled with oil and function as glands. Uniseriate glands composed of 3 or 4 cells also recorded by Solereder, and short-stalked, capitate glands in *Comptonia asplenifolia* (L.) Aiton and '*Myrica esculenta*'. Golden-yellow, balloon-shaped glands with short stalks composed of a few cells and unicellular heads, the latter containing oil when young but contents becoming resinified when older, recorded by Youngken (2491) as occurring with varying frequency in several species. Orange-red, bowl- to saucer-shaped glands mixed with golden-yellow glands of the type just mentioned, also recorded by the same author in *M. cerifera* Linn. Simple, unicellular **hairs,** sclerified at the base, also occur in many species. **Cuticle** frequently granular or, more rarely, striated. **Epidermis** for the most part composed of small cells with straight or sinuous anticlinal walls; papillose on the lower surface in *M. gale* especially around the stomata. **Hypoderm,** consisting of 2 layers beneath the adaxial surface of the leaf, recorded in *M. javanica* Bl. **Stomata** confined to the lower surface; ranunculaceous; those of *M. cordifolia* Linn. restricted to deep pits. Vascular bundles of the **midrib** accompanied by arcs of sclerenchyma, those of the smaller veins vertically transcurrent by elongated cells with wide lumina. **Petiole** (Fig. 307 B–C), in transverse sections through the distal end, exhibiting a massive, shallow, crescentic vascular strand with the vessels arranged in radial rows in *Comptonia asplenifolia* (Fig. 307 C), *Myrica gale* (Fig. 307 B), and *M. mexicana* Humb. et Bonpl. ex Willd.; with a smaller, lobed, shallow vascular arc in *M. cerifera* Linn. Petiolar vascular strands in all of the above species supported on the abaxial side by a narrow zone of thick-walled, 'pericyclic' fibres. A large mass of fibres also present between the ends of the crescent on the adaxial side in *M. mexicana*. Base of the petiole supplied by 3 vascular bundles, but these fuse higher up forming an arc of xylem and phloem in the distal end. Solitary and/or clustered **crystals** occur beside the vascular bundles. Rosette crystals also recorded by Youngken (2491) in the palisade cells, and crystal-sand in the palisade tissue of *M. gale*.

AXIS

YOUNG STEM (Fig. 307 D)

Cork originating below the epidermis; component cells sclerosed only on the inner tangential wall. **Cortex** of North American species examined by Youngken (2491) somewhat spongy; including solitary and small groups of stone cells in some, but not all, species. **Pericycle** including fibres and stone cells in the form of a continuous or interrupted ring. **Phloem** containing solitary and grouped sclerenchymatous elements in *Comptonia asplenifolia* (L.) Aiton; devoid of sclerenchyma in *Myrica gale*; dissected by the triangular distal ends of the medullary rays. Ends of the sieve tubes provided with several approximately circular sieve plates arranged in a longitudinal row. **Xylem.** Primary vascular structure appearing, in transverse sections through a young internode, as a lobed ring of slightly separated vascular bundles. Secondary xylem, in slightly older stems, forming a continuous cylinder traversed by medullary rays 1–5 cells wide. Vessels with scalariform perforation plates or simple perforations. **Pith** usually small; consisting of thick-walled cells in *M. gale* and in the American species of *Myrica* examined by Youngken (2491). **Crystals** of calcium oxalate secreted in solitary and clustered forms; present in the unlignified tissues and sometimes occurring attached to the pericyclic fibres or in crystalliferous fibres in the phloem. **Secretory cells,** with contents variously described as mucilaginous or resinous, sometimes present in the cortex. Tanniniferous materials often abundant.

WOOD (Fig. 308 A–C)

Vessels small (mean tangential diameter less than 100 μ) and often very small (25–50 μ), e.g. in *Myrica cerifera* Linn. and *M. gale* Linn.; typically exclusively solitary, but with few to numerous radial multiples in *M. gale*; usually 35–60 per sq. mm., but sometimes more than 100, e.g. in *M. cerifera*: ring-porous or nearly so in some temperate species, e.g. in *M. gale*, and often with very few vessels in the late wood of this species. Perforation plates all scalariform and typically with fewer than 15 bars in some species, e.g. *M. cerifera* L., *M. faya* Ait., *M. gale*, *M. integrifolia* Roxb., *M. javanica* Bl., *M. mexicana* Humb. et Bonpl. ex Willd., and *M. nagi* Thunb. (sometimes with up to 30 bars); with both simple and scalariform plates in others. Intervascular pitting usually opposite, sometimes intermediate between opposite and scalariform, e.g. in *M. nagi*, and alternate in *M. gale*. Pits to ray and wood parenchyma small and round, similar in size to the opposite intervascular pitting. Mean member length 0·6–0·95 mm. **Parenchyma** apotracheal, as cells scattered among the fibres and sometimes in contact with the vessels (Fig. 308 A); tending to form uniseriate lines in *M. gale*. Strands of 4–8 cells. Crystals reported (1154) in occasional specimens. **Rays** almost wholly uniseriate in *M. gale*, usually up to about 4 cells wide in other species, but up to 8 cells in some specimens of *M. nagi*; usually less than 1 mm. high, but higher in *M. nagi*; uniseriates numerous, composed almost entirely of square to upright cells in some species, e.g. *M. gale*, *M. javanica* (1154), and *M. nagi*, composed of mixed upright and procumbent cells in others, e.g. in *M. cerifera*; 8–20 rays per mm.; multiseriate rays heterogeneous (Kribs's Types II A and B), commonly with 4 or more marginal rows of upright cells; sometimes with sheath cells; solitary crystals occasionally present (1154). **Fibres** typically with numerous, distinctly bordered pits on all walls, but pits less numerous and borders small in *M. gale*. Walls thin except in *M. gale*. Mean length about 1·0–1·4 mm.

Root Nodules

According to Bottomley (239, 240), the root nodules of *Myrica gale* originate as lateral branches of the tetrarch roots. Three branches usually arise laterally near the end of each primary nodule, and, by repetition of this process, 'cluster' nodules are produced. Bottomley recognized 4 zones in each mature nodule. (i) An apical meristem. (ii) An 'infection thread' area. (iii) A bacterial zone comprising most of the cortical tissue and consisting of enlarged cells filled with bacteria. The cortical cells become infected before the young branch emerges from the old root. (iv) A basal region devoid of bacteria, composed of cells filled with oil drops. This gradually encroaches on and replaces all of the other zones. Bottomley secured experimental evidence that the bacteria in the nodules are capable of fixing nitrogen.

The structure of the root nodules in certain North American species of *Myrica* has been examined by Youngken (2491), who was apparently unaware of Bottomley's earlier work. Youngken's examination led to conclusions similar to those of Bottomley, and he identified the organism which occurs in the nodules as an *Actinomyces*. Concerning this organism he says: 'The *Actinomyces* not only confines itself to the cortex of the tubercular root, it later works its way into the tracheae of these structures, passes into the pitted vessels of the main roots, thence into those of the stems, and, conveyed by the transpiration stream gradually upward, is carried through the axes of catkins so as finally to reach the flowers, bracts and fruits. In these it confines its existence to the parts corresponding to the mediocortex of the root tubercles, namely the mesophyll and outer mesocarp regions respectively.'

Rhizome

The rhizome, in the species examined by Youngken, differs from the aerial stem in having fewer layers of cork cells; larger intercellular spaces; more rounded cells and fewer or no sclerenchymatous elements in the cortex; fewer fibres in the phloem; slightly broader medullary rays; less numerous but wider vessels in the xylem; larger pith cells with thinner walls; fewer or no crystals in the cortex and pith.

ROOT

Roots from seedlings and more mature plants of North American species have been described by Youngken (2491). Root hairs present; endodermis provided with thickened walls; component cells filled with 'gummy-lignin'. Primary vascular structure tetrarch. Tyloses frequent in the vessels. Rosette crystals present in the cortex.

ECONOMIC USES

A waxy material is secreted by several species of *Myrica*, and that from *M. cerifera* Linn. has been used in the manufacture of candles. Bayberry bark, usually said to be derived from the root of the same species, possesses tonic and astringent properties and is used to a certain extent in medicine.[1] The bark, when prepared for commercial use, is in pieces 2–15 cm. long, 0·5–2·0 cm. broad, and 1–2 mm. thick. The outer surface is whitish, but reddish-brown where the cork has been removed. Smoothed transverse surfaces show fibres scattered between the medullary rays in the yellow-brown inner portion. Microscopical features include prismatic crystals of calcium oxalate, some of which occur in axial rows of rectangular cells; thick-walled parenchyma of which the component cells are filled with a yellowish-brown substance; simple or 2–3 compound starch grains, the individual components being up to 12 μ in diameter; groups of stone cells. Youngken (2491, 2494) has reported that the highly tanniniferous bark from the root, rhizome, and aerial stems of *M. cerifera* is used commercially. The stem bark includes a more or less continuous ring of fibres and stone cells in the pericycle. Pericyclic sclerenchyma is absent from the root, whilst, in the rhizome, isolated groups of thin-walled sclerenchymatous cells are present. According to Youngken, the bark from these different parts of the plant can be distinguished even when powdered.

GENUS DESCRIBED

Myrica.*

* Represented in the Kew slide collection.

LITERATURE

(i) *On General Anatomy*

Bottomley **239**, **240**, Youngken **2491**, **2494**.

(ii) *On Wood Structure*

den Berger **182**, Giordano **786**, Greguss **2522**, Janssonius **1154**, Kanehira **1206**, Lecomte **1334**, Record **1783**, **1843**, **1851**, Record and Hess **1886**, Yamabayashi **2478**.

256. CASUARINACEAE

(FIG. 309 on p. 1296; FIG. 310 on p. 1300)

SUMMARY

(i) GENERAL

A family of xerophytic trees with a habit somewhat recalling that of *Equisetum*. It comprises the single genus *Casuarina*, of which many species

---

[1] The Bayberry, according to Rehder (1901A), is *Myrica pennsylvanica* Lois., whilst *M. cerifera* Linn. is the Wax Myrtle. Some of the species of *Myrica* mentioned by Youngken do not appear to be recognized by other authorities.

occur in Australia, and others in Malaya, New Caledonia, &c. The peculiar structure of the shoot system has been described by Macklin (1412), whose morphological concepts agree with those previously expressed by de Cordemoy (473). The primary assimilatory branches are attached in whorls to larger branches, which are in turn similarly arranged on still more mature shoots. The assimilatory branches (Fig. 309 A) consist of a series of segments or internodes, on the outside of which there are longitudinal ridges and furrows. Whorls of leaves at the nodes are interpreted as being concrescent with the stem throughout the length of the internode above, on which they form the ridges or 'phyllichnies'. At the next higher node the distal portions of the leaves, united by their lateral margins, form a sheath which covers the base of the next internode. The sheath ends in a number of teeth which represent the free tips of the leaves. The number and shape of the leaves vary considerably in different species and, according to de Cordemoy, also within a species. The leaves of each succeeding internode alternate with those above and below so that the furrows, representing the spaces between them, are also alternately arranged.

Simple or branched **hairs** (Fig. 309 D–E) occur in the furrows between the ribs, where they serve to protect the **stomata** (Fig. 309 B) which are rubiaceous and orientated at right angles to the longitudinal axis of the branch. The **assimilatory tissue** (Fig. 309 A) is confined to the ribs. In some species there is a single mass of chlorenchyma on the inside of a band of fibres situated immediately below the epidermis at the apex of each rib. In other species the sclerenchyma appears to be T-shaped in transverse section, with the stem of the T forming a ridge extending from the hypodermal fibres towards a more deeply seated leaf-trace bundle. The length of the stem of the T varies from species to species, and in those in which it is well developed, the chlorenchyma is divided into 2 symmetrical masses. The chlorenchyma is bounded internally by an **'external endodermis'**, first noted by Boodle and Worsdell (237), which dips beneath the furrows. An outer ring of **vascular bundles** with V-shaped xylem groups, one of which occurs opposite each rib, although sometimes referred to as 'cortical' are more correctly to be interpreted as leaf-traces, especially if the ribs are regarded as concrescent leaf tissue. The leaf-trace bundles unite with those of the main cauline system at the nodes. Transfusion tracheids (Fig. 309 C) occur between the leaf-trace bundles. An **endodermis** separates the 'cortical' tissue from the **cauline vascular bundles** which alternate with the leaf traces. The cauline vascular bundles are separated from one another by broad medullary rays in some species, but, in others, the xylem forms an almost continuous ring traversed by narrow rays. Vessels mostly with simple perforations; scalariform plates occasional. The ribs of 'phyllichnies' become cut off in older stems by **cork,** initially formed below the furrows but subsequently extending across the proximal ends of the ribs. In some species, e.g. in *C. inophloia* F. v. Müll., according to Francis (708), the old stems become longitudinally furrowed, large aggregate rays being associated with the indentations. Variations in the appearance of transverse sections of young stems are valuable in the identification of species, but de Cordemoy (473) has pointed out that the number of ribs and the amount of sclerenchyma in them sometimes vary considerably in specimens of a single species obtained from different localities.

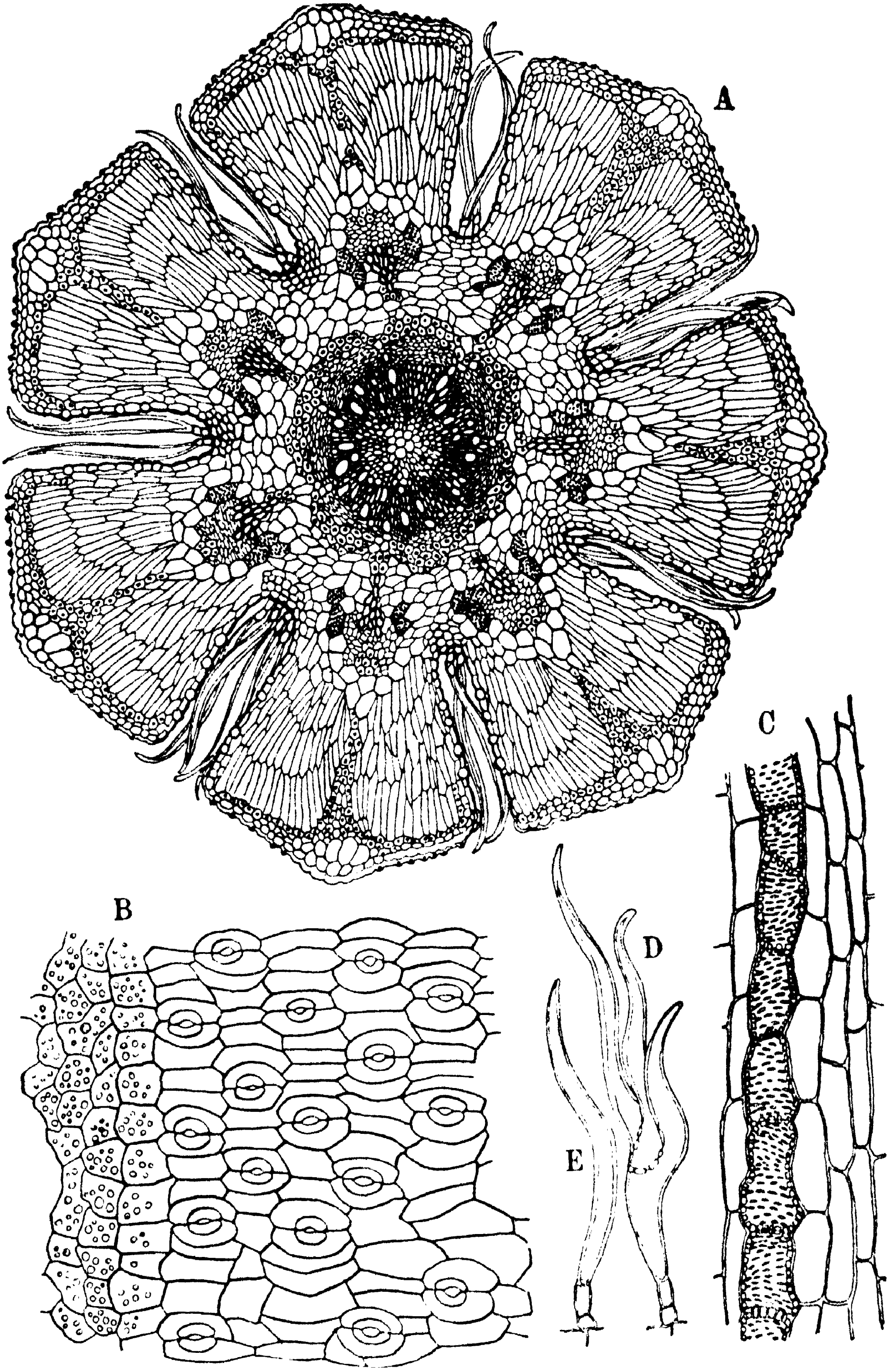


Fig. 309. *CASUARINACEAE*

(ii) WOOD

Vessels solitary and often with an oblique pattern, perforation plates typically simple, but very occasionally scalariform, intervascular pitting alternate and very small, pits to parenchyma similar, members of medium length. **Parenchyma** apotracheal, diffuse and in narrow bands. **Rays** commonly of 2 distinct sizes, the larger often 'aggregate', but sometimes with rays not more than 4 cells wide and not of 2 sizes; homogeneous. **Fibres** with distinctly bordered pits, of medium length. **Vasicentric tracheids** sometimes present.

YOUNG STEM

The main characteristics of a young stem have been given in the 'Summary'. The following descriptions are intended to give an idea of the differences in the structure of individual species:

(i) C. EQUISETIFOLIA Linn. (Fig. 309 A)

Number of ribs and grooves inconstant in material from different regions according to de Cordemoy (473), e.g. Seychelle Islands 7, Madagascar usually 7–9 but a sample with 17 obtained from the west coast of the island, Australia 8, New Caledonia 10–12, cultivated in Provence 10. **Epidermis** of the ribs devoid of stomata, and composed of cells with somewhat thickened outer walls enclosing small, highly refractive bodies. **Stomata** confined to the furrows, orientated transversely to the longitudinal axis of the branch; rubiaceous. Lamellae situated in the cellulose portion of the dorsal and ventral walls of the guard cells said by Solereder to be indicative of affinities with the Gymnosperms. **Hairs** of 2 kinds situated in the furrows. (i) Uniseriate trichomes each having 2 short basal cells and a longer terminal one with thicker walls. (ii) Somewhat similar but branched hairs. **Hypoderm** of the ribs composed of 1 or more layers of parenchyma, followed internally by fibres. The latter appear in transverse sections as T-shaped groups, with the vertical portion of the T extending down the centre of each rib towards the phloem in the more deeply seated leaf-trace bundles. Shape of the T-shaped fibre groups stated by de Cordemoy (473) to vary in specimens from different localities, e.g. stem of the T sufficiently long to divide the chlorenchyma into 2 well-defined groups in specimens from Madagascar, but much less well developed in material grown in the Mediterranean region. The remainder of each rib is usually composed of 2 groups of radially elongated palisade cells separated from one another by the stem of the T-shaped fibre group. Portion of the branch below the level of the furrows consisting of thin-walled parenchyma with **leaf-trace bundles** embedded in it opposite the ribs. Each leaf-trace bundle consists of weakly developed xylem towards the inside, and phloem towards the outside, the whole being supported by a sheath of fibres. **Cauline vascular bundles** of the central cylinder separated from one another by rather broad medullary rays; accompanied by groups of sclerenchyma at the outer margin. **Phloem** partly composed of sieve tubes with sieve plates arranged in a scalariform manner. Secondary phloem including stone cells and fibres. **Leaf sheath** similar in structure to the ribs of the stem, but supported by transverse bundles of fibres. Cluster **crystals** present in the parenchymatous tissues, but tending to be replaced by solitary types in old material. Crystals also present in some of the phloem fibres.

(ii) C. CHAMAECYPARIS Poiss.

Branch quadrangular, slightly winged at the corners, each wing containing sub-epidermal sclerenchyma, the latter being continued in the form of a ridge extending towards a leaf-trace bundle. Palisade parenchyma developed below all other parts of the circumference, except at a point on each of the lateral surfaces where 'cortical' parenchyma extends to the epidermis, which bears hairs at these points. Stomata present wherever palisade parenchyma borders directly on the epidermis.

(iii) C. LEUCODON Poiss.

Similar to *C. chamaecyparis*, but with the 4 corners rounded. Hairs absent. A sub-epidermal band of sclerenchyma present in the middle of each of the lateral surfaces.

(iv) C. NODIFLORA Forst., C. ANGULATA Poiss., and C. DEPLANCHEANA Poiss. var. *genuina* differ from (ii) and (iii) in the absence of sclerenchymatous ridges connecting the sub-epidermal sclerenchyma with the leaf-trace bundles.

(v) C. DEPLANCHEANA Poiss. var. CRASSIDENS.

Branches rounded-quadrangular in outline. Internal cortical parenchyma extending to the epidermis only at 4 points, each in the centre of one of the lateral surfaces. Palisade tissue present elsewhere beneath the epidermis, except where traversed by numerous radial ridges of sclerenchyma.

(vi) C. RUMPHIANA Miq.

Palisade tissue forming a continuous sheath below the epidermis.

(vii) SPECIES BELONGING TO THE 'DISTYLA COMPLEX'

Species belonging to the 'Distyla complex' examined by Macklin (1412) fall into 2 more or less distinct groups. (A) 'Stricta' type. Each of the ridges supported by a T-shaped group of fibres with the horizontal portion immediately below the epidermis, the stem of the T extending nearly to the leaf-trace bundles. Clear cells, with pitted, lignified walls, present amongst the fibres. Two symmetrical masses of chlorenchyma present, one on either side of the stem of the T. Transfusion tracheids occur beneath the chlorenchyma between the leaf-trace bundles. Besides *C. stricta* Ait., the following species exhibit similar structure: *C. distyla* Vent., *C. paludosa* Sieb., '*C. pusilla* Macklin', *C. rigida* Miq., and '*C. striata* Macklin'. These species are often distinguishable from one another by minor variations in the length of the stem of the T-shaped groups of fibres. (B) 'Muelleriana' type. Differing from the 'Stricta' type in the absence of T-shaped groups of fibres from the ribs, sclerenchyma being restricted to a band below the epidermis. Chlorenchyma in each rib in the form of a single mass. This type of structure observed by Macklin in *C. baxteriana* Miq., *C. muelleriana* Miq., *C. suberosa* Ott. et Dietr., and *C. thuyoides* Miq., but *C. baxteriana* and *C. suberosa* tending towards the 'Stricta' type.

WOOD (Fig. 310 A–C)

Vessels medium-sized (mean tangential diameter 100–200 μ) or slightly smaller and occasionally tending to be of 2 distinct sizes, e.g. in *Casuarina* *stricta* Ait. non Miq.; exclusively solitary; often with a loose oblique pattern; usually between 5 and 20 per sq. mm., but more numerous in some species or specimens, e.g. in *C. glauca* Sieb. and *C. stricta*; spiral thickening not observed, but reported (1679, 2158) to be occasionally present. Perforations typically simple, but the smaller vessels very occasionally with scalariform plates; Solereder refers to peculiar forms of scalariform plates near the primary wood, as described by Boodle and Worsdell. Intervascular pitting alternate, small to minute; pits to ray and wood parenchyma similar. Solid deposits sometimes present. Mean member length about 0·4–0·65 mm. **Parenchyma** apotracheal, as scattered cells and short to continuous bands 1–2 cells wide (Fig. 310 A). Commonly containing chambered crystals. Strands usually of 6–8 cells. **Rays** varying in type between (*a*) of 2 distinct sizes, the smaller uniseriate and the larger sometimes consisting of very wide single rays (as in *Quercus*), but more often of large rays dissected into smaller units and forming 'aggregate' rays, e.g. in *C. torulosa* (Dry.) Ait. (Fig. 310 C), and (*b*) rays of all sizes up to 4 cells wide and without 'aggregate' rays, e.g. in *C. equisetifolia* L. and *C. lepidophloia* F. v. Müll. (525). 'Aggregate' rays in *C. inophloia* F. v. Müll., according to Francis (708), are associated with the indentations in old stems. The large rays sometimes up to 3 cm. high. Usually about 12 rays per mm. Homogeneous (Kribs's Type I). Chambered crystals sometimes present, e.g. in *C. glauca*. **Fibres** with distinctly bordered pits that are equally numerous on both radial and tangential walls. Walls moderately to very thick. Mean length about 1·0–1·1 mm. A few **vasicentric tracheids** sometimes present, e.g. in *C. equisetifolia*.

ROOT NODULES

The root nodules in *Casuarina* have been examined, amongst others, by Aldrich-Blake (11), Chaudhuri (379), McLuckie (1470), and Miehe (1515). The nodules are modified lateral rootlets which branch profusely to form 'coralloid' masses, from which short-lived, fibrous roots radiate outwards. Each nodule is covered with cork except near the growing apex, and includes a cortex consisting of large parenchymatous cells interspersed with fibres, an endodermis, and a central stele. The apical meristem is free from bacteria, but there is a region immediately behind it which contains 'infection threads' of bacteria, below which there is an extensive zone of cells containing living bacteria, followed in turn by a basal zone in which the bacteria are inactivated and reduced to 'bacteroids'. McLuckie demonstrated that the bacteria are similar to those in the root-nodules of the Leguminosae, and, like them, capable of fixing atmospheric nitrogen. It is interesting to note, however, that Chaudhuri found that *Casuarina* plants from which bacterial nodules were absent did not appear to suffer, nor was inoculation with the appropriate organism found to induce any benefit in the host.

TAXONOMIC AND PHYLOGENETIC NOTES

It has already been pointed out that the ribs or 'phyllichnies' on the stem of *Casuarina* have been interpreted by de Cordemoy (473) and other workers as leaves fused to the stem, only the tips being free. If this interpretation is correct, the mesophyll structure may be regarded as having become inverted,

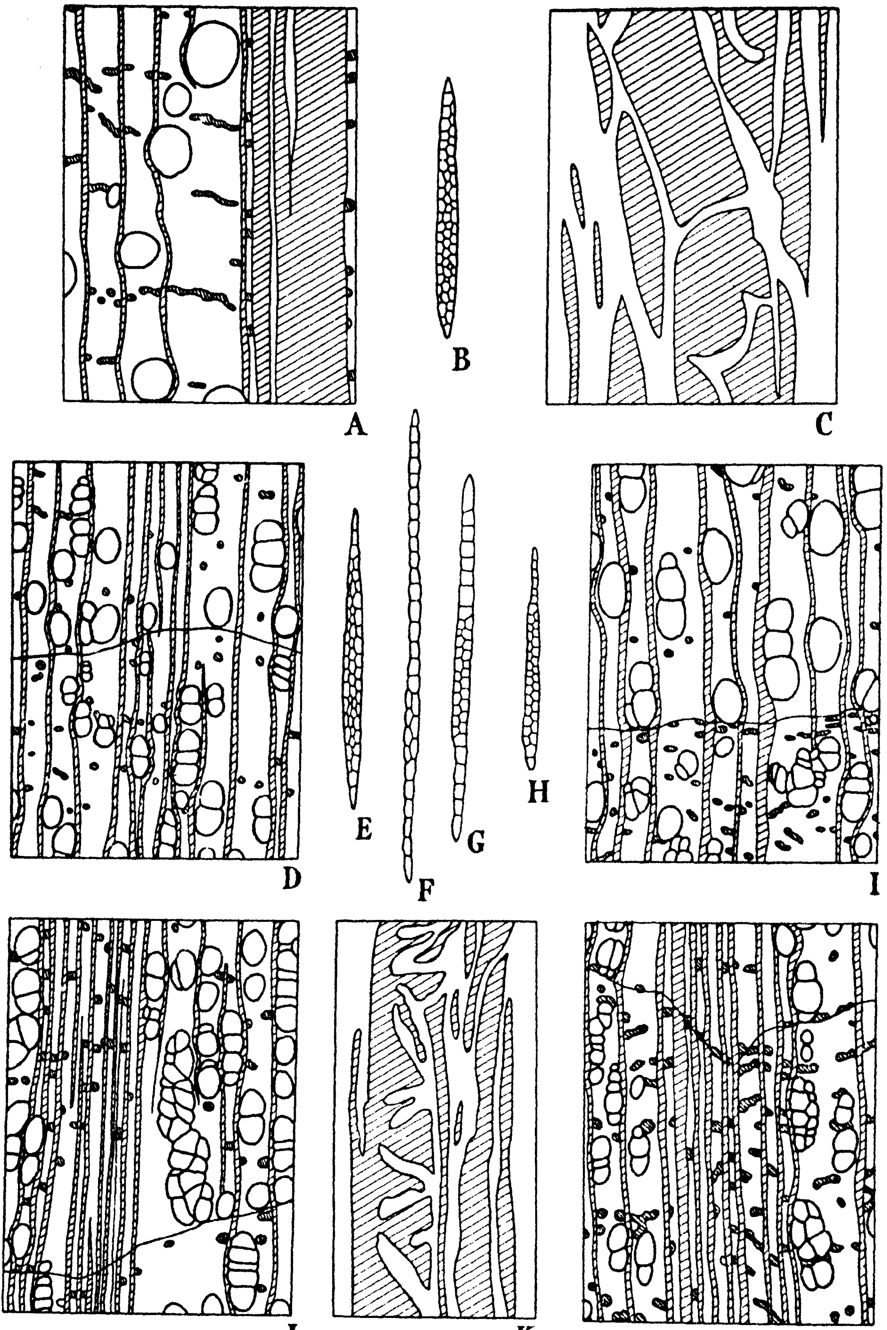


FIG. 310. *CASUARINACEAE*, A–C; *CORYLACEAE*, D, G, H, and K–L; *BETULACEAE*, E–F and I–J

A, *Casuarina torulosa* (Dryand.) Ait. B, *C. equisetifolia* Linn. C, *C. torulosa* (Dryand.) Ait. D, *Ostrya virginiana* K. Koch. E, *Betula pubescens* Ehrh. F, *Alnus nepalensis* D. Don. G, *Carpinus japonica* Blume. H, *Ostrya virginiana* K. Koch. I, *Betula lutea* Michx. J, *Alnus glutinosa* Gaertn. K, *Corylus avellana* Linn. L, *Carpinus betulus* Linn.

because the abaxial surface is the one which is exposed on the outside of the stem. de Cordemoy further believes that the 'external endodermis' has developed phylogenetically by the fusion and tangential orientation of the endodermal layers which originally surrounded the median vascular strands of the leaves. According to the same author the transfusion tracheids have also arisen in response to the morphological changes just described. To use de Cordemoy's own words a rib may be described as a

> 'feuille épaissie, longuement décurrante, concrescente par la face ventrale à l'entre-nœud, s'insérant au nœud immédiatement inférieur; épaississement déterminé par le tissu palissadique et chlorophyllien développé dans la partie externe ou dorsale du mésophylle, dont le type de structure est, par suite, renversé; nervure médiane comprenant une méristèle dont les principales modifications sont la conséquence de ce type de structure résultant lui-même de l'adhérance de la feuille; endoderme particulier déployé en un arc endodermique tangentiel sous-jacent au parenchyme chlorophyllien dorsal; faisceau libéro-ligneux à système vasculaire en *V* et tissu conducteur de transfusion d'origine péridesmique, qui établit la corrélation physiologique nécessaire entre le système vasculaire du faisceau et le tissu à chlorophylle'.

These changes are thought to have arisen in response to xerophytic conditions.

de Cordemoy has drawn attention to the superficial resemblances between *Casuarina* and the pteridophytic genus *Equisetum*. He even suggested that the origin of the Casuarinaceae, like that of *Equisetum*, is to be sought amongst the extinct plants of the *Calamodendron* type, but this interesting idea cannot be accepted unless supported by much more definite evidence than is at present available. The rays of *Casuarina* played a considerable part in the 'aggregate' ray hypothesis of Jeffrey (see p. xxxv).

ECONOMIC USES

The timbers are reputed to be hard to work and difficult to season and are of little importance, except sometimes as a source of fuel.

GENUS DESCRIBED

Casuarina.*

* Represented in the Kew slide collection.

LITERATURE

(i) *On General Anatomy*

Aldrich-Blake **11**, Boodle and Worsdell **237**, Chaudhuri **379**, de Cordemoy **473**, Francis **708**, Macklin **1412**, McLuckie **1470**, Miehe **1515**, Wood **2457**.

(ii) *On Wood Structure*

Bailey **69**, Baker **104**, den Berger **179**, den Berger and Endert **183**, Burgerstein **310**, Dadswell **525**, Dadswell and Record **533**, Desch **574**, Foxworthy **705**, Francis **708**, Greguss **2522**, Howard **1088**, Janssonius **1154**, Kanehira **1206**, **1209**, Pearson and Brown **1679**, Record **1843**, **1851**, Tupper **2295**.

257. BETULACEAE

(FIG. 310 on p. 1300; FIG. 311 on p. 1302; FIG. 312 on p. 1306)

SUMMARY

(i) GENERAL

Trees or shrubs mainly from north temperate regions, but also occurring in South America, the Himalayas, &c. Some species, especially those from the extreme northern limits of the family, are very dwarf in habit. The leaf is usually dorsiventral, but occasionally isobilateral or composed wholly of palisade cells. Unicellular **hairs** and glandular scales are common. The **epidermis** is mucilaginous. The ranunculaceous **stomata** are confined to the lower surface. In the young stem, the **cork,** perforated by large horizontal lenticels, forms the familiar, thin, paper-like layers on the outside of the bark; the **pericycle** contains a composite and continuous ring of sclerenchyma when relatively young, but this becomes broken when older; the secondary **phloem** includes stone cells; the **xylem** forms a closed cylinder traversed by narrow rays. Both solitary and clustered **crystals** occur.

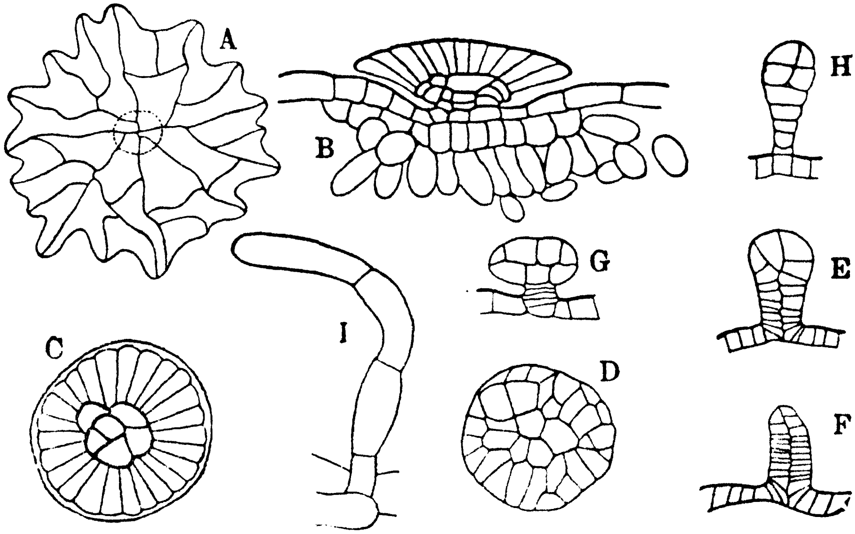


FIG. 311. *FAGACEAE*, A and I; *BETULACEAE*, B–D; *CORYLACEAE*, E–H

A, *Castanopsis chrysophylla* A. DC. B–D, Peltate glands of *Betula pendula* Roth.; B, in transverse section; C, glandular disk seen at a low, and D at a high, focus. E–F, *Corylus avellana* Linn. G, *Ostrya virginiana* K. Koch. H, *Carpinus betulus* Linn. I, *Quercus barnetto* Tenore.—A–D and I by Solereder, E–H after Boubier.

(ii) WOOD

Vessels small, sometimes with a loose oblique pattern, perforation plates scalariform, intervascular pitting moderately large and opposite to minute and alternate, pits to parenchyma similar, members of medium length to very long. **Parenchyma** diffuse and terminal. **Rays** up to 3 or 4 cells wide or exclusively uniseriate, sometimes aggregated, homogeneous. **Fibres** with small, but distinctly bordered, pits; of medium length to moderately long. Occasional **tracheids** reported.

LEAF

Usually dorsiventral, but with the mesophyll consisting wholly of palisade-like cells except around the veins in *Alnus glutinosa* Gaertn. Simple, unicellular **hairs** recorded in species of *Alnus* and *Betula*, and uniseriate types in *Alnus*. Bristle hairs at the margin recorded by Lutz (1404) in *Betula verrucosa* Ehrh. Glandular scales (Fig. 311 B–D) also occur in both genera, each scale consisting of a short but broad stalk composed of low, suberized cells, and a shield-like head made up of cells appearing to be polygonal in surface view, but resembling a palisade in sections of the gland. The mode of development of these glands has been described for *Alnus* by Dormann (599). According to the same author, a large proportion of the glands secrete a high molecular polyterpene, the latter occurring also in the epidermal cells of the young leaf in *Betula* and *Populus* (see p. 1316). **Epidermis** frequently mucilaginous; papillose on the lower surface in certain species. **Hypoderm** consisting of a single layer of cells of unequal size, situated below the upper epidermis, in numerous species of *Alnus*. Cells of the hypoderm like those of the epidermis, sometimes mucilaginous. **Stomata** usually confined to the lower surface, but present on the upper side as well, e.g. in *A. orientalis* Decne.; surrounded by several irregularly arranged epidermal cells (ranunculaceous). **Mesophyll,** when dorsiventral, including 1–3 layers of palisade cells. Vascular bundles of the large **veins** accompanied by sclerenchyma; those of medium size vertically transcurrent (see also under 'Ecological Anatomy'). **Petiole** (Fig. 312 A, C), in transverse sections through the distal end, when examined at Kew, exhibiting a deep, sinuously crescentic vascular strand in *A. glutinosa* and *A. incana* Moench. (Fig. 312 C). Median vascular strand less deeply crescentic and not sinuous in *Betula lenta* Linn. (Fig. 312 A) and *B. papyrifera* Marsh. Subsidiary strands in the wings noted in *Betula*. According to Solereder, 3 or more separate bundles enter the base of the petiole in both genera. Vessels in the petiolar xylem arranged in very definite radial rows, especially in *Alnus*. All petiolar vascular strands supported by fibres in the pericyclic region. **Crystals** more frequently clustered than solitary, but both types often present in a single species. Interspecific differences in the structure of the leaf of both genera have been described by Lutz (1404).

AXIS

YOUNG STEM (Fig. 312 B)

Cork always originating in the outer part of the cortex. The familiar white, easily detachable cork with transversely elongated lenticels, so characteristic of the birches, consists of alternating layers of tabular thick-walled cells and scarcely flattened, thin-walled cells filled with minute white granules of betulin. Cork cells of *Alnus* almost tabular. Outer part of the primary **cortex** always collenchymatous. Inner part of the cortex of *A. glutinosa* Gaertn. containing large, intercellular spaces separated by tangentially elongated cells. **Pericycle** including a composite and continuous ring of sclerenchyma when relatively young, but sclerenchyma becoming interrupted in older specimens of *Betula alba* Linn. Secondary **phloem** including groups of stone cells; the proportion of sclerosed elements varying in different species of *Betula*, according to Cousins (486). **Xylem** in the form of a more or less continuous cylinder traversed by rays 1–4 cells wide. Vessels with scalariform perforation plates. **Pith** almost or quite homogeneous; commonly triangular or Y-shaped in transverse sections. Solitary and cluster **crystals** present in the primary cortex; solitary crystals noted particularly in association with the pericyclic sclerenchyma. **Secretory cells** with unidentified but probably mucilaginous and tanniniferous contents, abundant in the unlignified tissues.

WOOD (Fig. 310 E–F and I–J)

Vessels small (50–100 μ mean tangential diameter) or slightly larger in some species of *Betula*; with numerous multiples of up to 3 cells and usually with some multiples of 4 or more cells; often with a loose, oblique pattern; usually about 9–30 per sq. mm. in *Betula* and more numerous (35–75) in *Alnus*. Perforation plates scalariform, with about 20, or fewer, bars in *Betula* and rather more in *Alnus*; occasionally reticulate in the latter. Intervascular pitting typically opposite and moderately large in *Alnus*, alternate and minute in *Betula*; pits to ray and wood parenchyma similar to the intervascular pitting. Tyloses common. Mean member length 0·6–1·2 mm., average 0·9 mm. or, according to Tippo (2261), 0·73 mm. **Parenchyma** apotracheal, rather sparse, as cells scattered among the fibres and along the ring-boundaries; the terminal parenchyma often in continuous bands in *Betula*; Tippo (2261) refers to metatracheal bands 1–3 cells wide in *B. cylindrostachya* Wall. Strands usually of 8 cells. **Rays** up to 4, occasionally 5, cells wide in *Betula*, uniseriate or partially biseriate in *Alnus*; commonly aggregated in *Alnus* (Fig. 310 J) and rarely (1886) in *Betula*. Forsaith (691) notes that at high altitudes 'aggregate' rays may be lacking from *Alnus*, and the rays of *Betula alba* var. *cordifolia* (Regel) Fernald. are mostly uniseriate; with moderately numerous to rather few uniseriates in *Betula*; 7–15 rays per mm.; homogeneous (Kribs's Types I and III). **Fibres** with rather few pits, which tend to be more numerous on the radial than on the tangential walls, the pits with small, but distinct, borders. Walls of medium thickness. Mean length 1·1–1·8 mm. **Tracheids.** Tippo (2261) reports some tracheids mixed with the fibre-tracheids in both genera. Hale (869) has observed trabeculae (bars of Sanio) in both tracheids and parenchyma cells in *Alnus oregona* Nutt. **Growth rings.** Cambial periodicity and the development of growth rings have been studied by Lodewick (1386) in *Betula lutea* Michx. in North America and by Coster (481) in *Alnus maritima* Nutt. introduced into Java.

ECOLOGICAL ANATOMY

Vessels in the xylem of the young stem of *Alnus incana* Moench. described by Starr (2188) as larger in diameter but less numerous in 'swamp' forms, but total area of vessels greater in 'dune' forms of the same species. Keller (1231) found the ratio of vein length to unit area of leaf to be higher in xerophytic species of *Betula* than in those growing in damper habitats, and also in the upper than in the lower leaves of an individual plant.

ROOT NODULES

The nodules on the roots of *Alnus* are, according to Spratt (2176), modified lateral branches which contain nitrogen-fixing bacteria. In both of these respects the nodules resemble those of *Elaeagnus* (see Elaeagnaceae, p. 1187).

TAXONOMIC NOTES

Of the 6 genera in the 2 families Betulaceae and Corylaceae, Tippo (2261) regards *Betula* and *Alnus* as the most primitive, *Corylus* and *Ostryopsis* as intermediate, and *Carpinus* and *Ostrya* as the least primitive. He also considers these 2 families as on the whole on a lower plane of anatomical specialization than the Casuarinaceae.

ECONOMIC USES

Birch (*Betula pendula* Roth.) and Alder (*Alnus glutinosa* Gaertn.) are extensively used for plywood in northern Europe, and 2 North American species, *Betula lutea* Michx., Yellow Birch, and *B. lenta* Linn., Sweet or Cherry Birch, are much used for furniture and joinery.

GENERA DESCRIBED

FOR GENERAL ANATOMY AND WOOD STRUCTURE

Alnus,* Betula.*

* Represented in the Kew slide collection.

LITERATURE

(i) *On General Anatomy*

Cousins **486**, Dormann **599**, Keller, B. A. and E. F. **1231**, Lepeschkin **1361**, Löw **1397**, Lutz **1404**, Morvillez **1562**, Spratt **2176**, Starr **2188**, Sztankovits **2227**, Winkler **2440**.

(ii) *On Wood Structure*

Bailey **66, 69**, Besson **186**, Bienfait and Pfeiffer **197**, Bliss **207**, Brown, H. P. and Panshin **288, 289**, Chalk and Rendle **365**, Chowdhury **411**, Coster **481**, Dadswell and Record **533**, Forsaith **691**, Greguss **2522**, Hale **869, 870**, Hoare **981**, Howard **1088**, Jayme **1160**, Kanehira **1206, 1209**, Lodewick **1386**, MacDuffie **1408**, Nicoloff **1593**, Pearson and Brown **1679**, Record **1783, 1818, 1843, 1851**, Record and Hess **1886**, Record and Mell **1894**, Stone **2203**, Tang **2230, 2231**, Tippo **2261**, Tupper **2295**, Yamabayashi **2478**.

258. CORYLACEAE

(FIG. 310 on p. 1300; FIG. 311 on p. 1302; FIG. 312 on p. 1306)

SUMMARY

(i) GENERAL

A family of shrubs and small trees which occur in north temperate regions. Leaf dorsiventral, bearing unicellular and uniseriate hairs as well as club-shaped glands. The **epidermis** is frequently mucilaginous. The ranunculaceous **stomata** are confined to the lower surface of the leaf. In the stem, the **pericycle** contains a composite continuous ring of sclerenchyma when relatively young, but this becomes interrupted when older; the secondary **phloem** is stratified into fibrous and non-fibrous portions; the **xylem** is in the form of a continuous cylinder traversed by narrow rays.

(ii) WOOD

Vessels small, with numerous multiples of 4 or more cells, often with a loose oblique or radial pattern, with spiral thickening, perforation plates all

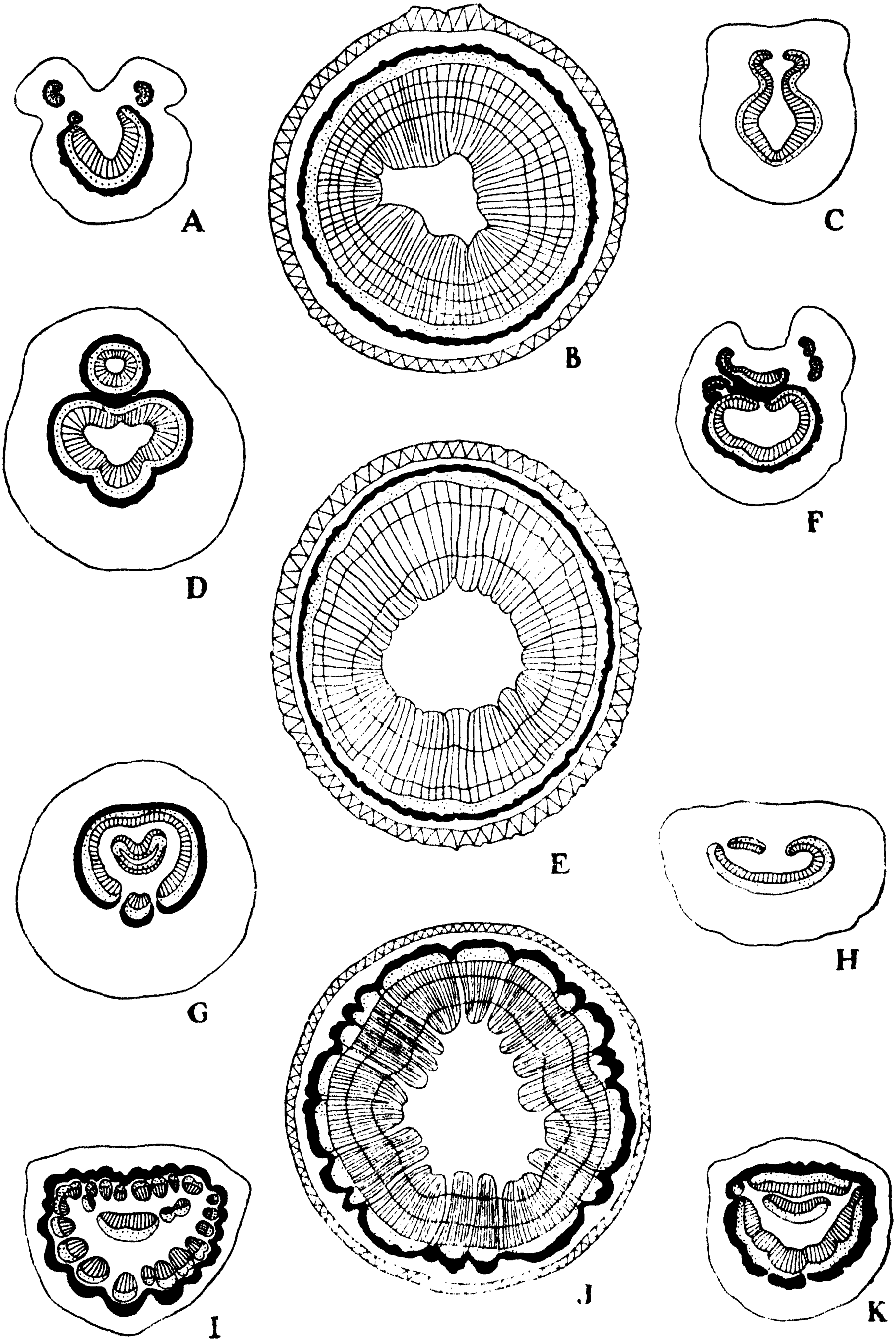


Fig. 312. *BETULACEAE*, A–C; *CORYLACEAE*, D–F; *FAGACEAE*, G–K

A, *Betula lenta* Linn. Petiole × 17. B, *B. lenta* Linn. Stem × 19. C, *Alnus incana* (L.) Moench. Petiole × 19. D, *Carpinus caroliniana* Walt. Petiole × 31. E, *Corylus avellana* Linn. Stem × 19. F, *C. avellana* Linn. Petiole × 14. G, *Fagus grandifolia* Ehrh. Petiole × 19. H, *Nothofagus antarctica* Oerst. Petiole × 32. I, *Castanea sativa* Mill. Petiole × 19. J, *Fagus grandifolia* Ehrh. Stem × 14. K, *Quercus cerris* Linn. Petiole × 19.

or predominantly simple, intervascular pitting alternate and moderately large, pits to parenchyma sometimes simple, members of medium length. **Parenchyma** diffuse and terminal. **Rays** up to 2 or 3 cells wide, commonly aggregated, homogeneous to slightly heterogeneous. **Fibres** with very small bordered pits; of medium length.

LEAF

Usually dorsiventral, but isobilateral structure recorded by Lutz (1404) in *Ostrya carpinifolia* Scop. **Hairs** including unicellular types in *Carpinus*, *Corylus*, *Ostrya*; uniseriate in *Corylus* and *Ostrya*. Cuticle of hairs striated in *Corylus avellana* Linn. and *Ostrya carpinifolia*. Club-shaped glandular hairs (Fig. 311 E–H) recorded in species of *Corylus*, and spherical, ellipsoidal, and disk-shaped types in *Carpinus* and *Ostrya*, both on the lamina and sometimes on the leaf teeth. **Epidermis** mucilaginous in species of *Carpinus* and *Corylus*. **Stomata** confined to the lower surface in all investigated species; ranunculaceous. Vascular bundles of the larger **veins** accompanied by arcs of sclerenchyma; those of medium size vertically transcurrent. **Petiole** (Fig. 312 D, F), in transverse sections through the distal end, exhibiting, in *Carpinus* and *Corylus*, a closed or nearly closed vascular strand of which the shape varies in different species, accompanied on the adaxial side by a smaller cylindrical strand in *Carpinus caroliniana* Walt. (Fig. 312 D), by a system of vascular arcs in *Corylus avellana* (Fig. 312 F), or by a more complex system of vascular arcs in the corresponding position on *C. colurna* Linn. Main petiolar vascular strand in the form of a deep, somewhat sinuous crescent in *Ostrya japonica* Sarg. and *Ostryopsis davidiana* Decne. Three vascular bundles enter the base of the petiole in all investigated species, according to Solereder. According to Sztankovits (2227), Hungarian species of *Carpinus* fall into 2 groups differing in the number of leaf traces. Solitary **crystals** situated in idioblasts appear as pellucid spots in *Carpinus* and *Ostrya*.

AXIS

YOUNG STEM (Fig. 312 E)

Cork arising in the outer part of the primary cortex; stratified into alternating layers composed of cells with wide lumina and tabular cells respectively in certain species of *Corylus* and *Ostrya*. Cork of *Carpinus betulus* Linn. composed of tabular cells with thick walls. Outer part of the primary **cortex** always collenchymatous; inner part provided with large intercellular spaces in *Ostrya virginiana* (Mill.) Koch. **Pericycle** containing a composite and continuous ring of sclerenchyma when comparatively young, but the ring sometimes becomes interrupted when older. Secondary **phloem** stratified into alternating layers consisting of strands of fibres and unthickened elements respectively in *Carpinus*, *Corylus*, *Ostrya*. **Xylem** constituting a closed cylinder, traversed by narrow, often uniseriate rays; vessels with simple perforations seen in *Carpinus* and *Ostrya* and scalariform plates in *Corylus* and *Ostryopsis*. Vessels in *Ostryopsis davidiana* Decne. confined to certain radii. See also under 'Wood'. **Pith** sometimes appearing angular in transverse sections, composed of thin- or thick-walled cells or heterogeneous according to the species. Peripheral cells sometimes with thicker walls than those of the larger central cells, e.g. in *Corylus avellana* L. and *C. colurna* L.

Mostly clustered, but also solitary, **crystals** frequent or abundant in the primary cortex. Solitary crystals observed within the pericyclic stone cells in all species of *Carpinus*, *Corylus*, *Ostrya*, and *Ostryopsis* examined. Clustered types also noted in the phloem of *Ostrya* and in the pith of *Corylus* and *Ostryopsis*. **Secretory cells** with unidentified but probably mucilaginous and tanniniferous contents abundant in the cortex, phloem, and pith of species of *Corylus*, *Ostrya*, and *Ostryopsis* examined at Kew; infrequent in or absent from *Carpinus betulus* and *C. caroliniana* Walt.

Branches of 'weeping' specimens of *Corylus avellana* exhibit small, inconstant differences from erect forms. In contradistinction to other trees with a weeping habit, Löw (1397) found the amount of mechanical tissue present to be not appreciably greater in the forms with pendent branches. Hungarian species of *Carpinus* said by Sztankovits (2227) to be divisible into 2 groups, differing in the structure of the fruit stalk and of the pericarp.

WOOD (Fig. 310 D, G, H, K, L)

Vessels small (50–100 μ mean tangential diameter), sometimes very small (25–50 μ) in *Corylus*; typically with numerous multiples of 4 or more cells, particularly in the late wood, the multiples of small vessels in the late wood of *Carpinus* and *Corylus* sometimes merging into radial groups of tracheids; sometimes with a loose oblique pattern in the late wood of *Carpinus* and *Ostrya* or a radial pattern in *Corylus*; usually 15–50 per sq. mm.; with a tendency to be ring-porous in some species of *Carpinus*, e.g. *C. turczaninowii* Hance; with spiral thickening. Perforation plates simple in most species of *Carpinus*, simple with a few scalariform plates in *Ostrya*, and wholly or predominantly scalariform in *Corylus* (with fewer than 20 bars) and *Ostryopsis* (2261). Intervascular pitting alternate and moderately large; pits to ray and wood parenchyma similar to the intervascular pitting, but with some simple and larger pits; sometimes unilaterally compound in *Corylus*; sometimes tending to be limited to the marginal rows of the rays, as in the Salicaceae. Tyloses present in *Ostrya*. Mean member length 0·5–0·8 mm.; average, according to Tippo (2261), 0·55 mm. but about 0·65 mm. for data available to the author. **Parenchyma** apotracheal, rather sparse, as cells scattered among the fibres and along the ring-boundaries (Fig. 310 D and L); Tang (2230) notes 'distinct tangential lines' in *Ostrya liana* Hu.; terminal parenchyma sometimes in continuous bands, e.g. in *Carpinus*. Strands usually of 8 cells. **Rays** up to 2 or 3 cells wide, but of more cells where aggregated; uniseriates numerous, composed wholly of procumbent cells or with single marginal rows of square cells; commonly aggregated in *Carpinus* and *Corylus* (Fig. 310 K and L); 10–17 rays per mm.; homogeneous (Kribs's Type II) in *Carpinus* and *Ostrya*, slightly heterogeneous (Type II B), with 1 marginal row of square cells, in *Corylus* and *Ostryopsis* (Tippo 2261). Crystals often present in idioblasts in *Carpinus* and *Ostrya*. **Fibres** with rather few pits, which tend to be more abundant on the radial than on the tangential walls; the pits with very small borders. Mean length 0·9–1·6 mm. **Tracheids** are occasionally associated with the late wood groups of vessels (see above) and Tippo (2261) notes that 'some of the fibre-tracheids are quite close to tracheids' in *Carpinus*, *Corylus*, and *Ostrya*.

TAXONOMIC NOTES

The dividing line between the Corylaceae and closely related families such as the Betulaceae is not very well defined. See also under Betulaceae.

ECONOMIC USES

The woods of the Common Hornbeam, *Carpinus betulus* Linn., and the Hop Hornbeams, *Ostrya carpinifolia* Scop. and *O. virginiana* (Mill.) Koch, are noted for their toughness.

Filbert nuts are obtained from cultivated varieties of the Common Hazel (*Corylus avellana* Linn.). Turkey nuts are obtained from *Corylus colurna* Linn. and possibly other species.

GENERA DESCRIBED

(i) FOR GENERAL ANATOMY

Carpinus,* Corylus,* Ostrya,* Ostryopsis.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Carpinus, Corylus, Ostrya, (Ostryopsis).

LITERATURE

(i) *On General Anatomy*

Löw **1397**, Lutz **1404**, Sztankovits **2227**.

(ii) *On Wood Structure*

Bailey **66**, **69**, Brown, H. P. and Panshin **288**, Chalk and Rendle **365**, Dadswell and Record **533**, Hale **870**, Holmes **1077**, Howard **1088**, Kanehira **1206**, Record **1783**, **1818**, **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**, Stone **2203**, Tang **2230**, Tippo **2261**, Tupper **2295**, Uspensky **2317**, Yamabayashi **2478**.

259. FAGACEAE

(FIG. 311 on p. 1302; FIG. 312 on p. 1306; FIG. 313 on p. 1312)

SUMMARY

(i) GENERAL

A family of trees from temperate and tropical regions, excluding tropical and southern Africa. The leaf is dorsiventral, or approximately to quite isobilateral in different species, and bears unicellular and stellate **hairs**, often accompanied by uniseriate or peltate **glands**. The **epidermis** is frequently mucilaginous. The ranunculaceous **stomata** are usually confined to the lower surface of the leaf. In the young stem, the **pericycle** contains a composite and continuous ring of sclerenchyma when relatively young, but this becomes interrupted when older. The secondary **phloem** includes fibres and/or stone cells, and is usually stratified into fibrous and non-fibrous portions.

(ii) WOOD

Vessels usually exclusively solitary, few and with a marked radial or oblique pattern, but small multiples sometimes moderately common, and very occasionally numerous and without pattern; perforation plates simple to predominantly scalariform, intervascular pitting intermediate, opposite or alternate, pits to parenchyma elongated and simple, members of medium length. **Parenchyma** apotracheal, diffuse or in fine lines. **Rays** either wholly uniseriate or of 2 distinct sizes, the larger 20–60 cells wide and very high, sometimes with aggregations of small rays, homogeneous or slightly heterogeneous. **Fibres** with simple to distinctly bordered pits and with some septa in 1 genus, of medium length to moderately short. **Vasicentric tracheids** usually common.

LEAF

Dorsiventral to isobilateral; mesophyll consisting wholly of palisade tissue in evergreen species of *Quercus* such as *Q. ilex* Linn. **Hairs** including a variety of types. (i) Simple, unicellular, with walls of varying thickness in species of *Castanopsis*, *Fagus*, *Quercus*. (ii) Clustered hairs, sometimes appearing stellate, but actually made up of 4–16 components, recorded in species of *Castanea* and *Quercus*; the abaxial side of the leaf described by Holm (1041) as completely covered with thick-walled, stellate hairs in *Castanea pumila* Mill. (iii) Glandular peltate hairs recorded by Solereder in *Castanopsis chrysophylla* A. DC. (Fig. 311 A) and in *Lithocarpus*. (iv) Uniseriate glands (Fig. 311 I), each with an enlarged basal cell but tapering towards the apex, observed by Lutz (1404) in several species of *Quercus*. Capitate glands with 2- to 4-celled stalks and 4- to 8-celled heads consisting of 2 layers of cells recorded by Lutz in *Quercus*. **Epidermis** composed of cells with straight or sinuous anticlinal walls; mucilaginous in certain species of *Fagus* and *Quercus*; sometimes tending to be papillose on the lower surface in *Quercus*, e.g. according to Holm (1041) near the stomata of *Q. alba* Linn. **Hypoderm** recorded by Solereder in a few species of *Quercus*, but none seen in the species examined by Lutz. **Stomata** confined to the lower surface; ranunculaceous. **Hydathodes** in small depressions recorded in *Nothofagus fusca* Oerst. by Betts (187). The 'cuticle' structure of some fossilized Fagaceae has been described by Bandulska (129). **Midrib** in *Fagus* including a central cylinder of xylem surrounded by groups of phloem; in *Quercus ilex* and *Q. suber* Linn. with 2, and, in other members of the Castaneae, 3 superimposed sectors of conducting tissue in the corresponding position (Lutz 1404). Vascular bundles of the larger **veins** said by Solereder to be accompanied by arcs of sclerenchyma, those of medium size vertically transcurrent. Veins vertically transcurrent by thin-walled tissue recorded by Holm (1041) in *Quercus alba* Linn. **Petiole** (Fig. 312 G, H, I, K), in transverse sections through the distal end, in species of *Castanea*, *Fagus*, and *Quercus* examined at Kew, exhibiting a vascular system consisting basically of a continuous or dissected cylinder, often flattened on the adaxial side, and enclosing one or more continuous or dissected and variously oriented arcs of xylem and phloem in the 'medullary' region. Petiolar vascular system less elaborate in *Nothofagus* (Fig. 312 H). No 'medullary' strands noted in *Quercus ilex* by Morvillez (1562). Vascular strand in *Q. suber* appearing as an approximately triangular, almost continuous arc with very much incurved ends, and in *Q. robur* Linn. as a somewhat similar but more dissected arc, no accessory bundles being present in the medullary region in either of these species. Petiolar vascular strand in *Nothofagus antarctica* Oerst. and *N. obliqua* Bl. consisting of a relatively shallow arc with one or sometimes both ends slightly separated from the remainder of the strand (Fig. 312 H). Petiolar vascular system strongly supported by fibres in the pericyclic region. Base of the petiole in *Castanea*, *Castanopsis*, *Fagus*, and *Quercus* said by Solereder to be supplied by 5 separate bundles. Further details concerning the petiole of Italian species of *Quercus* recorded by Bambacioni-Mezzetti (120). Clustered **crystals** present in the mesophyll, excluding the uppermost palisade layer, of all the species examined by Lutz (1404); solitary crystals, sometimes in large numbers, accompany the vascular bundles in *Quercus*.

AXIS

YOUNG STEM (Fig. 312 J)

Cork originating in the sub-epidermis in *Castanea*, *Fagus*, and *Quercus*, but seen to arise in the second layer below the epidermis in *Nothofagus*. Cork cells usually flattened and thick-walled in *Castanea* and *Quercus*; tabular and thin-walled in *Fagus sylvatica* Linn. Outer part of the primary **cortex** collenchymatous. **Pericycle** usually provided with a composite and continuous ring of sclerenchyma when sufficiently mature, but sometimes becoming secondarily interrupted when still older. **Phloem** containing strands of fibres and sometimes definitely stratified in *Castanea*, *Fagus*, and *Quercus*; fibres sometimes replaced by stone cells in *Fagus* or accompanied by them in *Quercus*. Phloem frequently traversed by the sclerosed distal ends of the medullary rays, e.g. according to Solereder in *Fagus sylvatica* and *Quercus suber* L. **Xylem** often in the form of a continuous cylinder traversed by narrow medullary rays, but dissected by broad, lignified primary rays in *Fagus grandifolia* Ehrh. (Fig. 312 J) and *F. sylvatica*. Broad primary rays tend to develop also in *Quercus*, but the large rays characteristic of the mature secondary xylem in this genus are represented by aggregations of narrow, mostly uniseriate rays along certain radii in young stems, e.g. in *Q. robur* L.; vessels often infrequent in or absent from the radii where the narrow rays are closely placed. Vessels with simple perforations or scalariform plates. **Pith** usually appearing angular or even stellate in transverse sections; generally homogeneous, but sometimes tending to be heterogeneous owing to a difference in size between the secretory cells and those constituting the remainder of the pith. Pith cells thick-walled, lignified, amyliferous in *Nothofagus* according to Betts (187). **Secretory cells,** with unidentified but probably mucilaginous or tanniniferous contents, abundant in the cortex and phloem in all of the species examined at Kew, and noted in the pith as well except in *Castanea sativa* Mill. Solitary and clustered **crystals** generally present in the unlignified tissues, clusters being rather more common than solitary types, their frequency and distribution varying from species to species. Solitary crystals, in the species examined at Kew, most frequent in the cell layer immediately external to the pericyclic sclerenchyma or else situated in the pericyclic stone cells themselves. Further details concerning Italian species of *Quercus* recorded by Bambacioni-Mezzetti (120).

WOOD (Fig. 313)

Vessels moderately small (50–100 μ mean tangential diameter) in *Fagus* and *Nothofagus*, medium-sized (100–200 μ) to large (more than 200 μ) in the diffuse-porous species of *Castanopsis*, *Lithocarpus*, and *Quercus*; with moderately numerous small multiples and clusters in *Castanea*, *Fagus*, and

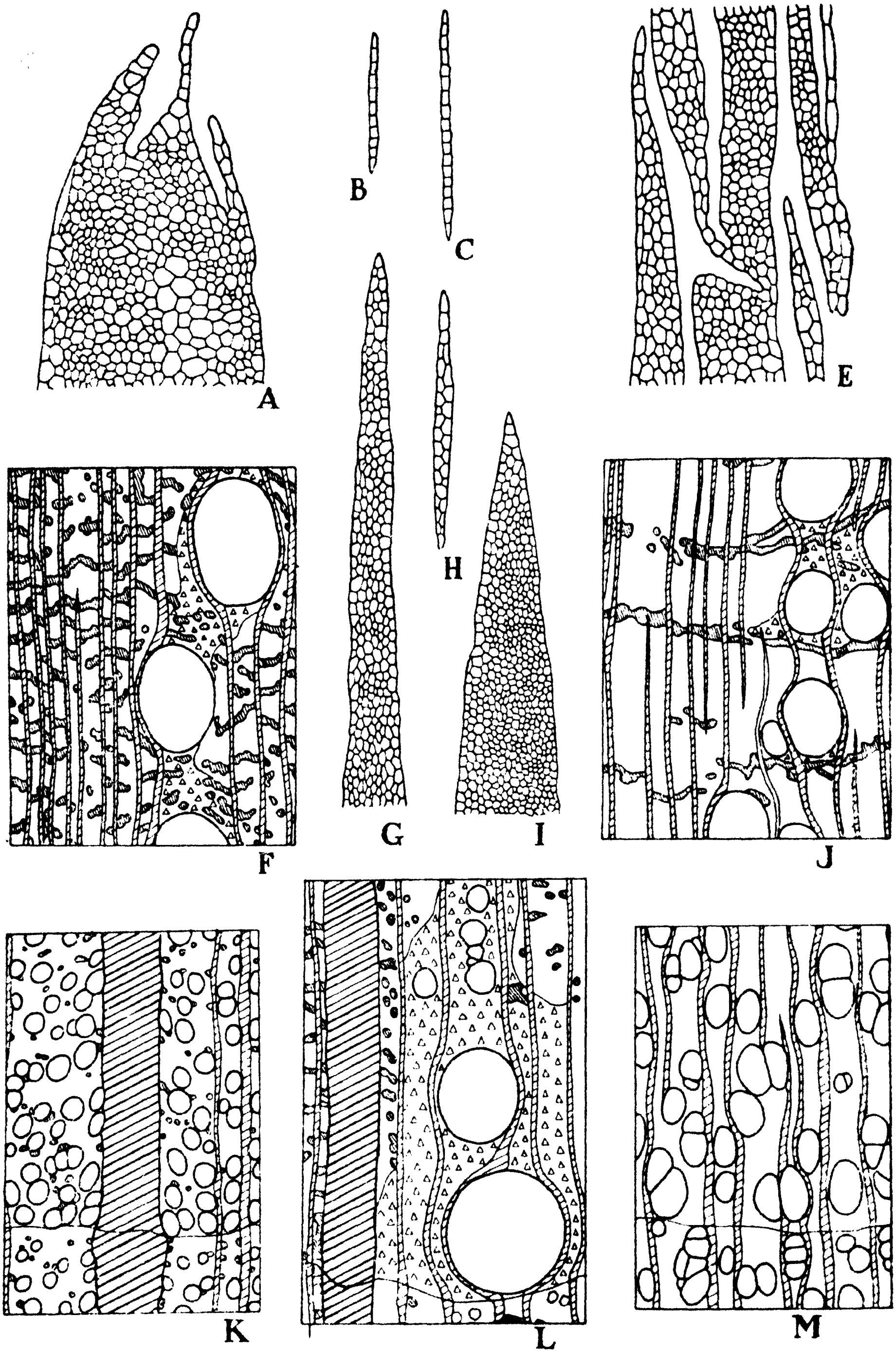


FIG. 313. *FAGACEAE*

A, *Lithocarpus edulis* Rehd. B, *Castanopsis sumatrana* A. DC. C, *Castanea dentata* Borkh. E, *Lithocarpus lucida* Rehder. F, *Castanopsis sumatrana* A. DC. G, *Quercus robur* Linn. H, *Nothofagus fusca* Oerst. I, *Fagus sylvatica* Linn. J, *Lithocarpus bennettii* Rehder. K, *Fagus sylvatica* Linn. L, *Quercus robur* Linn. M, *Nothofagus menziesii* (Hook. f.) Oerst.

Nothofagus, typically solitary in the other genera, though with some multiples in the late wood of the 'white' oaks; with a well-marked oblique or dendritic pattern (Fig. 313 F, J, and L), except in *Fagus* and *Nothofagus*; usually rather more than 50 per sq. mm. in *Fagus* and *Nothofagus* and sometimes more than 100 per sq. mm. in the latter (1652); mostly 2–9 per sq. mm. in the diffuse-porous species of the other genera; ring-porous in some temperate species of *Castanea*, *Castanopsis*, *Lithocarpus*, and *Quercus*; spiral thickening reported (525) to be occasionally present in *Nothofagus moorei* J. H. M. Perforation plates predominantly scalariform in *Fagus* and with a few scalariform plates in *Nothofagus* and, according to S. Williams (2434), in some of the evergreen species of *Quercus*; typically simple in the other genera and in most species of *Quercus*, but occasional vestigial scalariform plates may occur in any genus. Intervascular pitting opposite to transitional, and occasionally scalariform, in *Fagus* and *Nothofagus*, very rare in the other genera owing to the solitary vessels, probably usually alternate. Pits to ray and wood parenchyma typically large, elongated, and simple, with the long axes usually vertical, but horizontal in *Fagus* and *Nothofagus*. According to Bailey (78), the sieve-like structures reported by Jonsson (1192) are not true vestured pits. Tyloses often present; Tippo (2261) notes sclerotic tyloses in *Quercus engelmanii* Greene, and Williams (2435) that sclerosed and pitted tyloses occur in the 'Red Oak' or *Erythrobalanus* group of *Quercus*; Janssonius (1154) describes the occurrence of calcium carbonate in some Javanese species of *Quercus*. Mean member length 0·4–0·8 mm. **Parenchyma** apotracheal, typically as scattered cells or irregular uniseriate bands (Fig. 313 F and K), the bands more regular and commonly 2 cells wide (Fig. 313 J) in some individual species, e.g. *Lithocarpus edulis* Rehd., *L. encleisocarpus* (Korth.) A. Camus, and *Quercus lineata* Bl.; rare in *Nothofagus*. Chambered crystals sometimes abundant in *Castanopsis* and *Quercus*, and sometimes present in *Nothofagus* (1652). Strands usually of 8 cells. **Rays** exclusively uniseriate in *Castanea* and *Castanopsis* p.p. and in a few species of *Lithocarpus*, e.g. *L. sieboldii* (Makino) Nakai, *Nothofagus*, e.g. *N. cliffortioides* (Hook. f.) Oerst., usually up to 2 cells wide in *Nothofagus*; in most species of *Fagus*, *Lithocarpus*, and *Quercus* the rays are of 2 distinct sizes, uniseriate or many cells wide, though in *Fagus* there is sometimes a complete graduation from the smallest to the largest sizes; in rare species of *Quercus* the rays may all be very fine (1886), while in others, e.g. *Q. semecarpifolia* Smith, the 'large' rays may be only aggregations of small ones; the large rays commonly 20 or more cells wide, and up to 80 cells in some specimens of *Q. ilex* L., and very high (up to 10 cm.), except in *Fagus*. In the woods with large rays there is usually abundant evidence of the aggregation of small rays or the dissection of large ones, and a complete series of types from 'aggregate' to 'compound' can be found within the genus (Fig. 313 A and E). In *Quercus*, for example, according to S. Williams, the rays are commonly 'aggregate' in the evergreen species, only occasionally 'aggregate' in the other species of the sub-genus *Erythrobalanus*, and 'compound' in the sub-genus *Leucobalanus*. Uniseriates moderately to very numerous, composed wholly of procumbent cells or of procumbent and square cells. Usually 8–16 rays per mm.; homogeneous (Kribs's Types I and III), except in *Nothofagus* and some species of *Castanopsis* and *Lithocarpus*, in which there are commonly 1 or 2 marginal rows of square cells. Tippo (2261) points out that, near the pith, the rays, e.g. of *Lithocarpus* (*Pasania*), may be markedly heterogeneous, though they are homogeneous in more mature parts of the stem. It has been noted by Bailey (66) and others that large rays are completely lacking from the first-formed rings of *Quercus*, except in the neighbourhood of leaf traces, but extend to the pith in *Fagus* (see also 'Xylem' in 'Young Stem' on p. 1311). **Fibres** with rather few pits (except in *Fagus*), which tend to be more abundant on the radial than on the tangential walls, the pits having very small to distinct borders. In *Nothofagus* the pits are simple and a few of the fibres are usually septate. Walls moderately thin to very thick. Mean length 0·75–1·75 mm.; Sudworth and Mell (2216) list the mean, maximum, and minimum lengths of 35 species of *Quercus*, the mean lengths varying from 0·9 to 1·65 mm. **Vasicentric tracheids** characteristic of all the genera except *Fagus* and *Nothofagus*; often irregular in shape; mean length 0·6–1·1 mm.

ROOT

Seedling roots of *Castanea dentata* Borkh. said by Holm (1041) to become infected with **mycorrhiza** during the first year. Secondary cortex of the primary root of the same species containing 4 concentric bands of the thick-walled fibres sometimes mixed with stone cells.

TAXONOMIC NOTES

It has long been recognized that there are 2 types of wood structure in the Oaks, characteristic of the White and the Red or Black Oaks; these 2 groups correspond only approximately with the sub-genera *Leucobalanus* and *Erythrobalanus* respectively as at present defined. After an extensive study of other features besides the wood in the North American species, S. Williams (2433) proposed the following characters for separating the sub-genera: *Leucobalanus*, late wood pores angled, thin-walled; leaves devoid of spinose teeth or bristle shaped lobes; *Erythrobalanus* late wood pores rounded, thick-walled; leaves wholly or in part with bristle-tipped lobes, apex apiculate or margins with spiny teeth. If these diagnostic characters are accepted it will be necessary to transfer 8 species from *Leucobalanus* to *Erythrobalanus*. Williams considers that the evergreen Oaks, though forming a distinct group within *Erythrobalanus*, should not be given the status of a third sub-genus. Tillson and Muller (2257) consider that the anatomical characters of the wood alone do not constitute a basis for the sub-generic division of the American species of *Quercus* and only roughly indicate a possible division of the White Oak sub-genus.

Yatsenko-Khmelevsky (2486) has studied the woods of *Nothofagus* and, after noting that relatively advanced characters, such as the grouping of the vessels, exist side by side with primitive characters, such as the heterogeneous rays, which have almost disappeared from related genera, concludes that *Nothofagus* diverged very early from related genera and that the wood of its most primitive representatives probably resembled that of *N. cunninghamii* Oerst.

Tippo (2261) considers the Fagaceae to be more highly specialized anatomically than the Betulaceae.

The 'aggregate' and 'compound' rays of this family figured very prominently in the controversy of 1911–22 over the phylogenetic relationships of herbs and trees (see p. xxxiv et seq.).

ECONOMIC USES

This family produces some of the most important timbers in the world, including Oak (*Quercus*), Chestnut (*Castanea*), and Beech (*Fagus*) in the northern hemisphere and various species of *Nothofagus* (Southland Beech, Antarctic Beech, &c.) from the southern hemisphere. The tropical species of *Castanopsis* and *Lithocarpus* are not of importance, though their timbers are often of good quality. The true Oaks fall into 2 distinct groups; the White Oaks, corresponding approximately to the botanical sub-genus *Leucobalanus*, are more important commercially than the Red or Black Oaks, which correspond to the sub-genus *Erythrobalanus*. The timbers as a whole exhibit a very wide range of properties and have a correspondingly wide range of uses.

Commercial cork is derived chiefly from the bark of *Quercus suber* Linn. The galls on certain species of *Quercus* from south-east Europe and Asia Minor are collected and used as a source of tannin. Chestnuts are the edible nuts of *Castanea sativa* Mill., obtained chiefly from S. Europe. The seeds of the beech (*Fagus sylvatica* Linn.) are also edible, and in some regions constitute an important food for pigs.

GENERA EXAMINED

(i) FOR GENERAL ANATOMY

Castanea,* Castanopsis, Fagus,* Nothofagus,* Quercus.*

* Represented in the Kew slide collection.

(ii) FOR WOOD STRUCTURE

Castanea, Castanopsis, Fagus, Lithocarpus, Nothofagus, Quercus.

LITERATURE

(i) *On General Anatomy*

Bambacioni-Mezzetti **120**, Bandulska **129**, Betts **187**, Holm **1041**, **1069**, Lutz **1404**, Morvillez **1562**, Starr **2188**, Watkins **2367**.

(ii) *On Wood Structure*

Bailey **65**, **66**, **78**, Beekman **167**, den Berger **179**, **182**, den Berger and Endert **183**, Besson **186**, Betts **188–9**, Bienfait and Pfeiffer **197**, Brown, H. P. and Panshin **288**, **289**, Chalk and Rendle **365**, Coster **480**, **481**, Dadswell **525**, Dadswell and Record **533**, Desch **574**, Ebes **621**, Foxworthy **705**, Garratt **744**, Gerry and Scheffer **761**, Greguss **2522**, Groom **823**, **824**, **825**, Hale **870**, Howard **1088**, Isenberg **1124**, Janssonius **1154**, Jayme **1160**, Jonsson **1192**, Kanehira **1206**, **1209**, Langdon **1317**, Lodewick **1386**, Mulsow **1573**, Parham **1652**, Pearson and Brown **1679**, Record **1779**, **1783**, **1818**, **1843**, **1851**, Record and Hess **1886**, Record and Mell **1894**, Rendle **1915**, Stone **2203**, Sudworth and Mell **2216**, Tang **2230**, **2231**, Tillson and Muller **2257**, Tippo **2261**, Tupper **2295**, Williams **2433**, **2434**, **2435**, Yamabayashi **2478**, Yatsenko-Khmelevsky **2486**.

260. SALICACEAE

(FIG. 314 on p. 1318; FIG. 315 on p. 1322)

SUMMARY

(i) GENERAL

A widely distributed family which occurs in most parts of the world except Australia and the Malayan region, and consists of trees and shrubs belonging to the 2 genera *Populus* and *Salix*. The last of these includes some procumbent or almost herbaceous species. One of the most interesting anatomical features is the occurrence, in the distal end of the **petiole,** of one or more closed rings of xylem and phloem, which in *Populus* often appear superimposed vertically when viewed in transverse sections. In the young stem the sheaths of chambered **crystal fibres** around the groups of sclerenchyma in the secondary phloem of *Salix* are also very characteristic.

(ii) WOOD

Vessels moderately small, perforations simple, intervascular pitting alternate and large, pits to ray cells simple and limited to the marginal rows, members of medium length. **Parenchyma** terminal only. **Rays** exclusively uniseriate, heterogeneous or homogeneous. **Fibres** with simple pits, of medium length.

LEAF

Usually dorsiventral, but isobilateral structure recorded by Lutz (1404) in *Populus nigra* Linn., *Salix alba* Linn., *S. babylonica* Linn., and *S. purpurea* Linn., other species also tending to show similar structure. **Hairs** simple, unicellular, sometimes with contracted, thick-walled bases. Vesicular **glands,** lined with radially arranged secretory cells, recorded by Solereder as sometimes present in the leaf teeth of both genera, but noted by Lutz (1404) only in *S. alba*, *S. caprea* Linn., *S. nigricans* Sm., *S. pentandra* Linn. An aromatic, balsam resin is secreted from the glandular leaf teeth, the stipules and bud scales of certain species of *Populus*, the amount of secreted material varying from one species to another. According to Fehér (679) the secretion is from specialized, prismatic, epidermal cells, where it is first visible on the outer surface or between the cuticle and the cell wall, but never within the cells themselves. **Stomata** frequently present on both surfaces of the leaf; rubiaceous, sometimes with 2 subsidiary cells on either side of the pore, e.g. according to Lutz (1404) in *P. nigra* including var. *italica* Dur. **Epidermis** commonly including mucilaginous cells, the mucilage sometimes causing them to appear as if septate. **Hypoderm** occasionally present, e.g. according to Lutz (1404) beneath the adaxial surface in *Populus alba* L. and *Salix caprea* (near the vascular bundles), towards both surfaces in *Populus nigra*, and confined to within the lower epidermis in *P. nigra* var. *italica*, *Salix alba*, *S. babylonica*, *S. pentandra*; not clearly defined in *S. nigricans*. Vascular bundle of the **midrib** in *Populus* usually consisting, according to Lutz (1404), of a central xylem enclosing some pith, the xylem being surrounded by a heart-shaped phloem. Two superimposed, bicollateral bundles present in the corresponding position in *Salix*. Vascular strand of the midrib collateral in *Populus tremula* Linn. and *Salix reticulata* Linn. Three vascular bundles enter the base of the **petiole** in both genera, but change over to one or more rings of xylem and phloem towards the distal end. Petiole, in transverse sections through the distal end in species examined at Kew, exhibiting the distinctive and very characteristic vascular structure shown in Fig. 314 B, D, F. Several superimposed, continuous or interrupted circles of xylem and phloem present in species of *Populus* with laterally compressed petioles; with a single, cylindrical strand accompanied by 2 small bundles in each of the wings in *P. trichocarpa* Torr. et Gray; with a shallow arc of 3, widely spaced, cylindrical strands in *Salix lanata* Linn. Further details concerning the vascular structure throughout the length of the petiole in various species of both genera have been recorded by Morvillez (1555) and in *Populus* by Leach (1323), the last of these authors drawing attention to the similarity of the vascular structure in *Populus* petioles to that in the stems of certain lianes. Leach investigated the vascular structure in relation to the physical strains to which the petiole is subjected. Solitary and clustered **crystals** present, the former mostly situated around the vascular bundles, the druses being more widely distributed.

AXIS

YOUNG STEM (Fig. 314 C, E)

Cork always superficial. First-formed cork cells in *Populus* cubical, but later ones flattened. A few layers of cork cells, each with tangential thickenings to the outer wall, formed annually in *Salix*. A lignified phelloderm usually developed in *Populus*; a single phelloderm layer formed annually in *Salix* according to Akerman (10). Primary **cortex** collenchymatous towards the outside; including stone cells (Fig. 314 E), sometimes united to form a ring, in certain species of *Populus*. Stone cells said by Akerman (10) to be absent from the primary cortex in *Salix*. **Pericycle** in *Salix* including a ring of fibres when young, but this becomes broken into separate strands when more mature. Separate strands of fibres also common in *Populus*. Fibres said to be absent from the pericycle of creeping species of *Salix*. Secondary **phloem** also containing fibres; sometimes stratified into hard and soft portions. Groups of stone cells present in this tissue in species of *Populus* particularly in the ray tissue. **Xylem** forming a closed cylinder traversed by narrow rays. Vessels with simple perforations. **Pith** frequently stellate; heterogeneous; including fibres or stone cells in some species of *Populus* (Fig. 314 E). Deposits of calcium carbonate sometimes present in this tissue in material which is sufficiently mature. Solitary **crystals** common in chambered fibres forming sheaths around the groups of sclerenchyma in the secondary phloem. Solitary and clustered crystals also frequent in the unlignified tissues. **Secretory cells,** with unidentified, but probably tanniniferous, contents, noted at Kew in the phloem and pith of *P. trichocarpa* Torr. et Gray and in the cortex, phloem, and pith of *Salix lanata* Linn. Similar cells observed in other species by Graf (802).

It is well known that dormant root primordia occur in *Salix* stems, and that these develop very rapidly in twigs cut off and treated as stem cuttings. According to Carlson (343), who refers to earlier work on the same subject, the primordia in *S. cordata* Muhlenb. arise from meristematic cells in the outer part of the rays. The primordia appear in early June in the lower, but not in the 3 or 4 lowermost nodes of developing branches. They are formed at progressively higher levels in the branches later in the summer.

The initiation of cambial activity in the buds and its subsequent basipetal spread down the stem and thence along the roots has been studied in 2 species of *Populus* by Brown (279).

WOOD (Fig. 315 A–E)

Vessels moderately small (50–100 μ mean tangential diameter); solitary and in radial multiples of 1–5 cells; occasionally with a tendency to an oblique or tangential pattern; usually between 40 and 70 per sq. mm. but occasionally rather more numerous, e.g. in *Salix caprea* Linn. Perforations exclusively simple. Intervascular pitting alternate and large. Pits to ray cells characteristic; simple, similar in size to the borders of the intervascular pitting, and limited to the marginal rows of the ray. Tyloses often present. Mean member length 0·4–0·8 mm. **Parenchyma,** except for very rare cells scattered among the fibres, limited to the boundaries of the growth rings, varying from a few cells to continuous bands 1–2 cells wide. **Rays** typically uniseriate and less than 1 mm. high; Hermann (956) notes the occurrence of some biseriate rays in *Populus alba* Linn.; usually about 11 per mm.; heterogeneous (Kribs's Type III), with 1–3 marginal rows of square cells in *Salix*, and typically homogeneous in *Populus*; Hermann (956), however, refers to the rays of *P. canadensis* Moench. as heterogeneous. **Fibres** with simple pits, mostly on the radial walls; occasional septa reported by Solereder in *Salix alba* Linn., but not observed by the author. Walls thin. Mean length

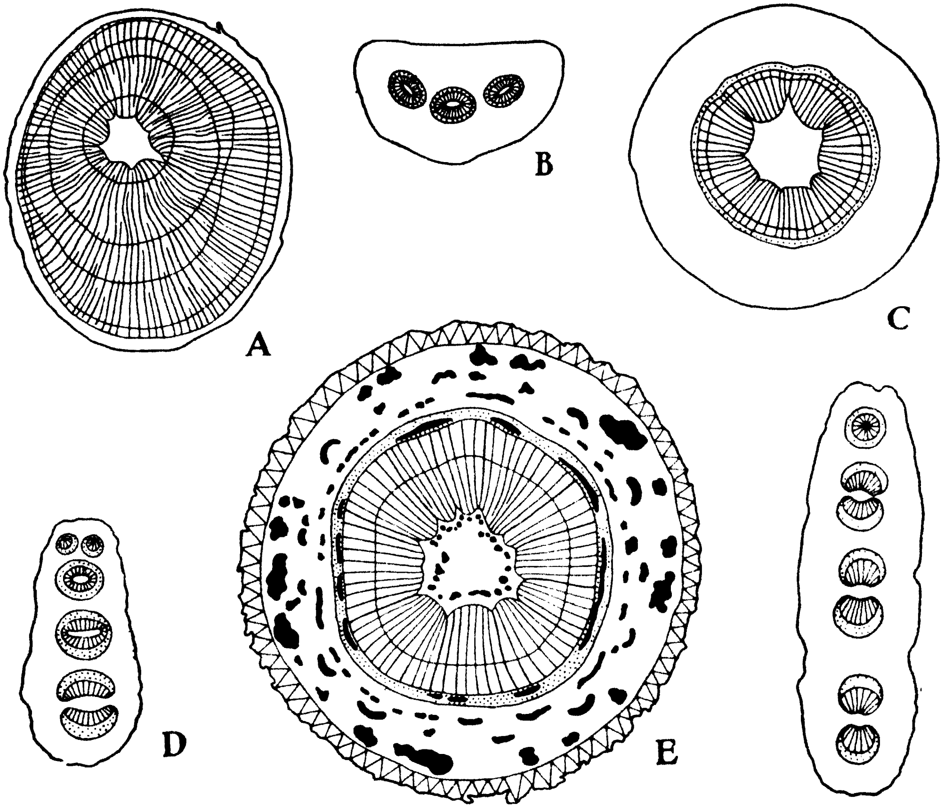


FIG. 314. *EMPETRACEAE*, A; *SALICACEAE*, B–F

A, *Empetrum nigrum* Linn. Stem × 19. B, *Salix lanata* Linn. Petiole × 13. C, *S. lanata* Linn. Stem × 8. Pericyclic fibres not shown. D, *Populus alba* Linn. Petiole × 19. E, *P. tremula* Linn. Stem × 19. F, *P. tremula* Linn. Petiole × 19.

0·9–1·3 mm. **Growth ring** development in *S. babylonica* Linn. has been studied by Coster (481) in Java.

BARK

The microscopical structure of the bark of numerous species of *Populus* and *Salix* has been described by Perrédès (1690). The important differences between the 2 genera are given as follows. *Populus.* Cork cells never thickened on the outer wall only. Stone cells invariably present in the phloem. *Salix.* Cork cells thickened on the outer wall only. Stone cells invariably absent from the phloem. Stone cells recorded in the old bark of *S. alba* Linn. by Akerman (10).

ECOLOGICAL ANATOMY

Populus balsamifera Linn. was the only one of the numerous plants belonging to various families examined by Starr (2188) in which the leaves of dune forms were no thicker than those of mesophytic specimens of the same species. Xerophytic specimens differed from mesophytic forms in having a thicker and more strongly ridged cuticle, deeper epidermal and palisade cells, and larger and more numerous vessels in the midrib. Xerophytic specimens of '*Populus deltoides*' seen by the same author to have 3 layers of palisade cells towards the upper and 2 towards the lower epidermis. Xerophytic specimens of '*P. deltoides*' also showed more angular stems and a definitely stellate pith.

TAXONOMIC NOTES

(i) FROM GENERAL ANATOMY

Gilg (768) has pointed out that, in his opinion, there are no reliable grounds for regarding the Salicaceae as derived from the Flacourtiaceae by reduction. In the Salicaceae the secondary phloem is typically stratified into hard and soft portions, whereas in the Flacourtiaceae this is not so. Crystalliferous fibres in the phloem are characteristic of the Salicaceae, but are unknown in the Flacourtiaceae. The hairs of the Flacourtiaceae are frequently more complex in structure than those of the Salicaceae. There are also chemical differences between the 2 families.

(ii) FROM WOOD STRUCTURE

The very short vessel members and their pitting and perforations indicate that this is a rather highly specialized family; this is confirmed by the character of the rays and fibres.

ECONOMIC USES

The Willows and Poplars, particularly the latter, are the source of considerable quantities of timber. That of the Aspens is used principally for book-paper and matchsticks; the rough-barked, North American species known as Cottonwoods often grow to very large sizes and produce lumber that finds its principal use for crates and boxes, though used also for pulp, plywood, 'excelsior', and other products. The wood of willow is very similar, but most of the species only form small or badly shaped stems. The wood is used to a small extent for the same purposes as poplar, except for pulp, but is probably most widely used for chip baskets; it is also used for artificial limbs, and in Great Britain the wood of cultivated, fast-grown stems of the Cricket-Bat Willow, *Salix alba* var. *caerulea* Sm., fetches very high prices.

Young, flexible stems of *Salix* are used in basket-making.

Genera Described

Populus,* Salix.*

* Represented in the Kew slide collection.

Literature

(i) *On General Anatomy*

Akerman 10, Brown, A. B. 279, Carlson 343, Fehér 679, Gilg 768, Graf 802, Leach 1323, Lutz 1404, Morvillez 1555, Perredes 1690, Starr 2188.

(ii) *On Wood Structure*

Bienfait and Pfeiffer 197, Brown, H. P. and Panshin 288, 289, Burgerstein 310, 312, Chalk and Rendle 365, Chowdhury 411, Coster 481, Greguss 2522, Hale 870, Hermann 956, Holden 986, Howard 1088, Jayme 1160, Jones 1191, Kanehira 1206, 1209, Nicoloff 1593, Pearson and Brown 1679, Record 1783, 1818, 1843, 1851, Record and Hess 1886, Record and Mell 1894, Stone 2203, Tang 2230, Williams 2430, Yamabayashi 2478.

261. LACISTEMACEAE

(FIG. 315 on p. 1322)

Summary

A family of shrubs and small trees belonging to the single genus *Lacistema*, which occurs in tropical America. The simple **hairs** with elongated pits in the basal cells are noteworthy, and also the somewhat complex vascular structure of the **petiole** and **midrib.** The wood exhibits the following characters. **Vessels** small, in long radial groups, perforation plates scalariform, intervascular pitting opposite and minute, pits to parenchyma similar, members very long. **Parenchyma** diffuse. **Rays** 2–4 cells wide and often more than 2 mm. high, markedly heterogeneous. **Fibres** septate, moderately long.

Leaf

The following particulars concerning the leaf structure have been recorded chiefly by Chirtoiu (395A). Lamina dorsiventral. **Hairs** varying in nature and frequency in different species, but always simple; those of *L. grandifolium* Schnitzl. 2- to 3-celled with thin transverse septa and thick outer walls. Basal cell of each hair sometimes provided with elongated pits. **Stomata** confined to the lower surface, usually surrounded by 3 or more cells not very clearly differentiated from those of the remainder of the epidermis; ranunculaceous. **Mesophyll** including 1–2 rows of palisade cells in different species. Palisade cells short in *L. grandifolium*, but more elongated, arranged in 2 layers, and serving as aqueous tissue in *L. pubescens* Mart. **Midrib** including a somewhat complex vascular system, the detailed structure of the latter varying to some extent according to the species. Midrib of *L. myricoides* Sw. including a closed vascular strand, consisting of an abaxial arc of xylem and phloem, accompanied, on the adaxial side, by 2 xylem masses between the ends of the crescent, the adaxial xylem masses have the form of interrupted circles partially enclosing some phloem, the whole vascular complex being surrounded by an interrupted cylinder of sclerenchyma. Midrib of *L. grandifolium* provided with a flattened, continuous cylinder of xylem and phloem, accompanied, on the adaxial side, by small, normally orientated bundles, the latter embedded in, and the whole vascular system surrounded by, sclerenchyma. **Petiole.** Vascular structure generally somewhat complex, and, like that of the midrib, varying in structure from species to species. Base of the petiole of *L. myricoides* supplied by a crescentic group of closely placed vascular strands with well-developed phloem, but not supported by 'pericyclic' sclerenchyma, 2 subsidiary bundles being present in the wings. Transverse sections through the middle of the petiole of the same species exhibit a circle of separate bundles surrounded by continuous phloem. Structure at the base of the petiole of *L. grandifolium* similar to that described for the corresponding position in *L. myricoides*, but middle part of *L. grandifolium* supplied by a closed, continuous xylem cylinder accompanied, towards the adaxial side, by about 7 small, collateral strands, the median one being just external to the phloem of the main cylindrical strand. Structure similar at the distal end in the same species, but vascular bundles supported externally by a certain amount of sclerenchyma. Cluster **crystals** present in the mesophyll and beside the vascular bundles, their frequency varying in different species. **Tannin** abundant.

AXIS

YOUNG STEM

Cork superficial; component cells often most strongly thickened on the inner tangential walls and contiguous portions of the radial walls. Primary **cortex** sometimes containing a few stone cells. **Pericycle** provided with a slightly interrupted ring of sclerenchyma, the latter described by Krause (1278A) as composed of isodiametric cells. **Xylem** in the form of a continuous cylinder traversed, according to Krause (1278A), by rays 1–2 cells wide; including radial rows of vessels with small quadrangular lumina and scalariform perforation plates. **Tannin** abundant in all tissues.

WOOD (Fig. 315 F and G)

Vessels very small (mean tangential diameter less than 50 μ) to moderately small (50–100 μ); typically with numerous radial multiples of 4 or more cells, which tend to be grouped so as to form radial lines; 25–50 per sq. mm. Perforation plates scalariform, often with more than 20 fine bars. Intervascular pitting opposite and minute; pits to ray and wood parenchyma similar to the intervascular pitting and distinctly smaller than the pits between parenchyma cells, sometimes unilaterally compound (1886). Mean length about 1·6 mm. **Parenchyma** apotracheal, as isolated cells scattered among the fibres. Strands of 8–12 cells. **Rays** up to 2–4 cells wide; multiseriate rays often 2 mm. high or more; uniseriates numerous, high, and composed mainly of tall upright cells; about 16 rays per mm.; markedly heterogeneous (Kribs's Type I), with many marginal rows of tall upright cells and sometimes with 2 or more separate multiseriate parts (Fig. 315 F). Solitary crystals sometimes abundant. Perforated ray cells common (358). **Fibres** with simple or faintly bordered pits, which are more numerous on the radial than on the tangential walls. Often septate. Walls often thick. Mean length about 2.0 mm.

TAXONOMIC NOTES

The taxonomic position of *Lacistema* has been much disputed, and the various affinities which have been suggested for the genus have been summarized by Krause (1278A). Krause himself believes the affinities of the genus to lie with those of the flacourtiaceous genus *Prockia* (see p. 125). It is noteworthy that the anatomical features of *Lacistema* are very unlike those of the Piperaceae and related families. This has been emphasized by Chirtoiu (359A), who, like Krause, believes *Lacistema* to be more closely related to the Flacourtiaceae than any other family. All the characters of the wood can be matched in the Flacourtiaceae, except for the diffuse parenchyma in *Lacistema*. The wood is of an unspecialized type.

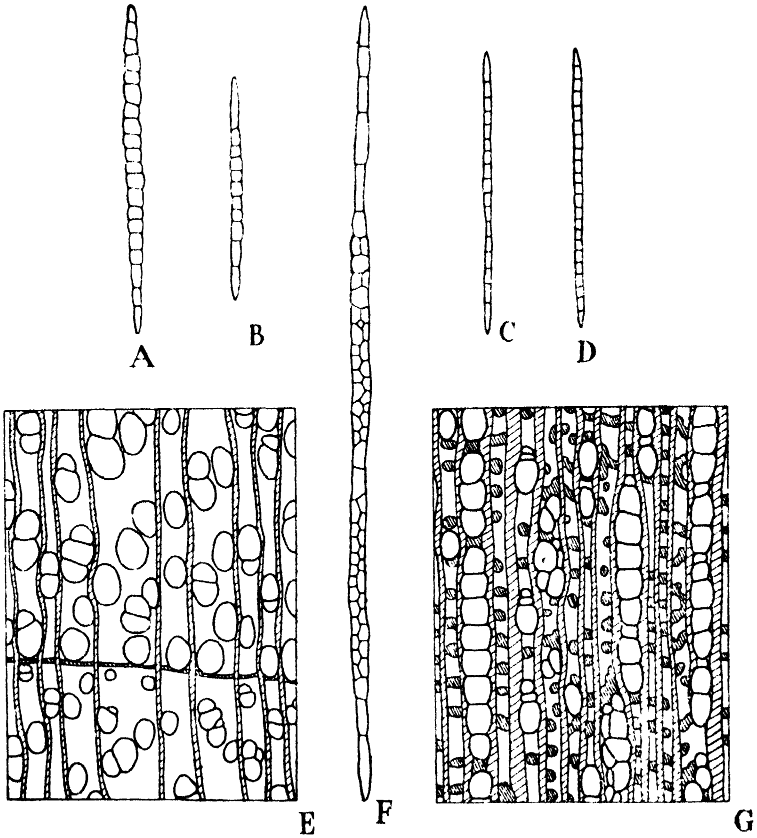


FIG. 315. *SALICACEAE*, A–E; *LACISTEMACEAE*, F–G
A, *Populus euphratica* Oliv. B, *Salix humboldtiana* Willd. C, *S. alba* Linn. var. *caerulea* Sm. D, *Populus tremuloides* Michx. E, *P. nigra* Linn. F, *Lacistema nana* Macbride. G, *L. aggregatum* (Berg.) Rusby.

GENUS DESCRIBED

Lacistema.

LITERATURE

(i) *On General Anatomy*
Chirtoiu 395A, Krause 1278A.

(ii) *On Wood Structure*
Chalk and Chattaway 358, Record 1851, Record and Hess 1886, Williams 2430.

262. EMPETRACEAE

(FIG. 314 on p. 1318; FIG. 316 on p. 1324)

SUMMARY

A small family comprising a few ericoid shrubs, chiefly from north temperate and Arctic regions. They possess rolled leaves, and exhibit a rather uniform vegetative structure. The following description of the anatomy of the leaf and young stem is based mainly on that by Solereder, but has been supplemented by fresh observations on *Empetrum nigrum* Linn.

LEAF

Leaf deeply furrowed on the lower side (Fig. 316), the groove eventually becoming almost closed by hairs and thus forming a central cavity. **Hairs** confined to the epidermis lining the central cavity; consisting of (*a*) glands with short, unicellular or uniseriate stalks and uni- or pluricellular, ellipsoidal heads and (*b*) simple, unicellular trichomes. Unicellular hairs sufficiently numerous to form a tangled mass in the central cavity of the leaf of *Ceratiola ericoides* Michx. and *Corema album* Don.; chiefly confined to the closely opposed leaf margins and becoming sufficiently interlocked to close the entrance to the central cavity in *Corema conradi* Torr. and *Empetrum nigrum* Linn. **Epidermis** of the outer surface composed of cells with very thick outer, and mucilaginous inner, walls. Epidermal cells lining the central cavity provided with thin outer walls. **Mesophyll** dorsiventral, consisting of a more or less typical palisade tissue below the adaxial epidermis, and of spongy tissue on the inside of the abaxial epidermis. **Vascular bundles** not accompanied by sclerenchymatous elements. **Crystals,** according to Solereder, secreted in the form of clusters and radially striate, concentrically stratified sphaerites in *Empetrum nigrum*; only clustered crystals recorded in *Corema album*. No crystals observed in a leaf of *Empetrum nigrum* cultivated at Kew.

AXIS

YOUNG STEM (Fig. 314 A)

Epidermis composed of cells with very thick outer walls. **Cork** arising in the pericycle; that of *Corema album* Don. consisting of cells with thickened inner tangential walls. Sub-epidermal cells of *Ceratiola ericoides* Michx. with the inner tangential walls sclerosed. **Pericycle** including very little sclerenchyma, but isolated fibres recorded in this region in *Empetrum* and bundles of fibres locally in the corresponding position in *Ceratiola.* Secondary **phloem** devoid of fibres. **Xylem** in the form of a continuous cylinder traversed by rays 1–2 cells wide. Vessels of all species scattered and about 24–30 μ in diameter; those of *Empetrum nigrum* Linn. angular, solitary, in oblique pairs and small, irregular clusters. Vessels with scalariform perforation plates sometimes accompanied by simple perforations. **Pith** of *E. nigrum* composed of moderately thick-walled, pitted cells.

WOOD

Vessels extremely small (mean tangential diameter less than 25 μ); almost exclusively solitary, apart from apparent tangential pairs due to overlapping ends; extremely numerous; tending to be ring-porous in *Empetrum nigrum* Linn. Perforation plates scalariform, with up to 10 bars, in *Empetrum*, mostly simple, but with a few scalariform plates in *Ceratiola* and *Corema*. Pits to ray cells small and round to slit-like. **Parenchyma** very scanty. **Rays** 1–2 cells wide; exclusively uniseriate in *Empetrum nigrum*; composed entirely of upright cells. **Fibres** with numerous, small, bordered pits on both radial and tangential walls.

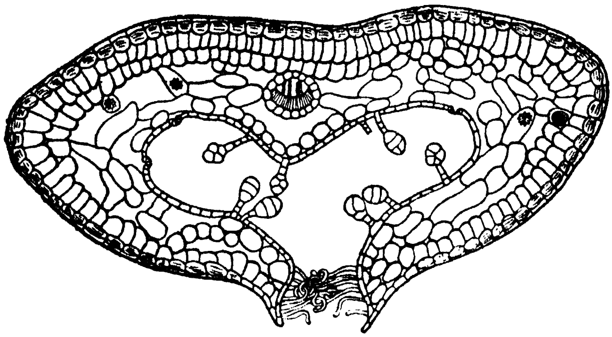


FIG. 316. *EMPETRACEAE*
Transverse section through the leaf of *Empetrum nigrum* L.—By Solereder.

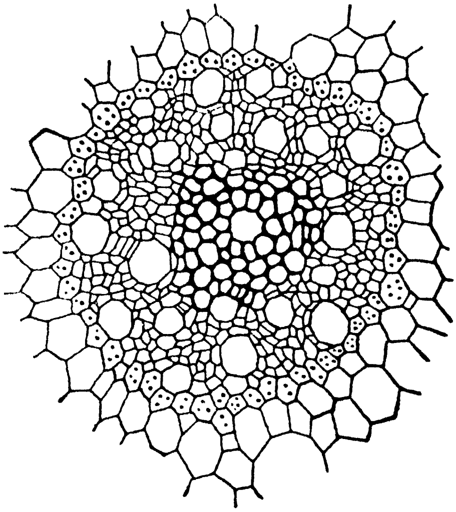


FIG. 317. *CERATOPHYLLACEAE*
Transverse section through the fibro-vascular system of *Ceratophyllum demersum* L.—After H. Schenck.

GENERA DESCRIBED

Ceratiola, Corema, Empetrum.*

* Represented in the Kew slide collection.

LITERATURE

On Wood Structure
Greguss 2522.

263. CERATOPHYLLACEAE

(FIG. 317 on p. 1324)

SUMMARY

A widely distributed family of submerged aquatic plants belonging to the single genus *Ceratophyllum*. The few species comprising this genus are devoid of roots and complete their flowering and fruiting below water. The only species which has received much attention from anatomists is *C. demersum* Linn. The following anatomical description is based mainly on that by Solereder.

LEAF

Segmented. Apices of the segments occupied by long, multiseriate shaggy **glands,** composed of cells filled, when young, with a rose-coloured oily substance said to be myriophyllin. Tannin present in the older glands; each gland accompanied on either side by a long, pointed, unicellular hair. Leaf elliptical or circular in transverse section, with a vascular **bundle,** devoid of vessels and surrounded by a parenchymatous sheath, situated towards the upper surface. **Epidermis** consisting of low cells containing more chlorophyll than the mesophyll; component cells polygonal in surface view. **Stomata** absent. Mesophyll traversed longitudinally by 3 large **air-canals** towards the lower side and 2 smaller ones towards the adaxial surface. Canals towards the lower surface separated from one another by septa consisting of a single layer of cells. **Secretory cells** with tanniniferous contents present in the mesophyll.

AXIS

STEM (Fig. 317)

Epidermis containing chlorophyll. **Stomata** absent. Peripheral part of the primary **cortex** collenchymatous, but inner part including a ring of air spaces, separated from one another by radial plates, each consisting of a single layer of cells. **Endodermis** well defined, containing starch and provided with casparian thickenings. Centre of the solitary **vascular strand** occupied by an axile air canal, surrounded by vertically elongated, amyliferous cells representing the xylem. Vessels absent. Tissue between the xylem and endodermis consisting of **phloem** made up of 2 rings of wide sieve tubes and companion cells embedded in parenchymatous ground-tissue. **Secretory cells** with tanniniferous contents and suberized walls present throughout the cortex.

GENUS DESCRIBED

Ceratophyllum.

LISTS OF FAMILIES IN WHICH CERTAIN DIAGNOSTIC FEATURES OCCUR

IN the following lists the inclusion of a family signifies only that the feature occurs in certain members of the family and not necessarily in every genus. The families in which the feature is especially common are shown in bold type; those in which it is infrequent or rare are given in italics.

HAIRS

THE taxonomic value of hair structure is well established. The various types are not always clearly defined, however, and their value for systematic purposes is lessened by the fact that many kinds occur in families which are generally thought to be unrelated, thus making it reasonably certain that the same type of hair must have been evolved along independent lines. Nevertheless, some kinds possess diagnostic value because of their restricted occurrence, whilst the combination of hair types is valuable in families where several or numerous kinds occur together. In using the following lists of hair types it must be remembered that they are incomplete and that the hairs have been classified on a somewhat arbitrary basis. Also that it is common for each type of hair to be restricted to certain genera and species in each of the families.

Stinging hairs

- Euphorbiaceae
- Loasaceae
- *Malpighiaceae*
- Urticaceae

Pearl glands

- Ampelidaceae
- *Caesalpiniaceae*
- *Moraceae*
- *Piperaceae*
- *Urticaceae*

Laticiferous hairs

- Compositae—Cichorieae

Vesicular or bladder-like hairs

- Chenopodiaceae
- *Combretaceae*
- *Compositae*
- Crassulaceae
- *Icacinaceae*
- Melastomaceae
- Myricaceae
- *Oxalidaceae*
- *Salicaceae*
- Umbelliferae

Snail-shaped glands

- **Burseraceae**

Salt glands

- *Acanthaceae*
- **Frankeniaceae**
- Tamaricaceae

Chalk glands

- **Plumbaginaceae**

Special type of mucilage hair

- Pedaliaceae

Arachnoid hairs

- **Compositae**
- *Crassulaceae*
- *Hydrophyllaceae*
- Plantaginaceae
- Polemoniaceae
- Rosaceae—Chrysobalanoideae

Calcified or silicified

- **Boraginaceae**
- Campanulaceae
- *Cornaceae*
- *Cucurbitaceae*
- *Gesneriaceae*
- *Hydrangeaceae*
- Hydrophyllaceae
- **Loasaceae**
- Moraceae
- *Polemoniaceae*
- *Scrophulariaceae*
- Ulmaceae
- *Verbenaceae*

Families with numerous types of hairs

- **Acanthaceae**
- Araliaceae
- **Boraginaceae**
- **Burseraceae**
- **Caesalpiniaceae**
- **Capparidaceae**
- **Caprifoliaceae**
- **Chenopodiaceae**
- **Cistaceae**
- **Compositae**
- **Connaraceae**
- Convolvulaceae
- **Cruciferae**
- **Dipterocarpaceae**
- Ebenaceae
- **Ericaceae**
- Escalloniaceae
- **Euphorbiaceae**
- **Fagaceae**
- **Flacourtiaceae**
- **Goodeniaceae**
- **Labiatae**
- Loganiaceae
- **Lythraceae**
- **Malvaceae**
- **Melastomaceae**
- **Meliaceae**
- **Mimosaceae**
- Orobanchaceae
- **Papilionaceae**
- **Polygonaceae**
- Rutaceae
- **Sapindaceae**
- **Scrophulariaceae**
- **Solanaceae**
- **Sterculiaceae**
- **Tiliaceae**
- **Turneraceae**
- **Umbelliferae**
- **Verbenaceae**

Non-glandular shaggy hairs

- Araliaceae
- Begoniaceae
- Cactaceae
- *Caesalpiniaceae*
- *Capparidaceae*
- Compositae
- Ericaceae
- Euphorbiaceae
- *Lythraceae*
- *Malpighiaceae*
- Malvaceae
- *Mimosaceae*
- Papaveraceae
- *Papilionaceae*
- *Polygonaceae*
- *Portulacaceae*
- Saxifragaceae
- *Valerianaceae*

Glandular shaggy hairs

- Aceraceae
- **Apocynaceae**
- *Asclepiadaceae*
- *Caesalpiniaceae*
- Ceratophyllaceae
- *Convolvulaceae*
- *Crassulaceae*
- *Cunoniaceae*
- Datiscaceae
- Ericaceae
- *Euphorbiaceae*
- *Gentianaceae—*
    - *Gentianoideae*
- *Geraniaceae*
- **Grossulariaceae**
- **Haloragaceae**
- *Linaceae*
- *Loganiaceae*
- *Lythraceae*
- Melastomaceae
- *Menispermaceae*
- *Mimosaceae*
- Monotropaceae
- *Ochnaceae*
- *Passifloraceae*
- *Plumbaginaceae*
- *Rhizophoraceae*
- Rubiaceae
- *Rutaceae*
- *Saxifragaceae*
- *Simarubaceae*
- *Violaceae*

Non-glandular, tufted

- *Araliaceae*
- *Begoniaceae*
- **Bixaceae**
- *Burseraceae*
- *Caesalpiniaceae*
- *Caprifoliaceae*
- Cistaceae
- *Cunoniaceae*
- Dipterocarpaceae
- Ebenaceae
- Euphorbiaceae
- Fagaceae
- *Flacourtiaceae*
- *Frankeniaceae*
- **Hamamelidaceae**
- *Hydrangeaceae*
- *Icacinaceae*
- Juglandaceae
- Labiatae
- *Lecythidaceae*
- *Linaceae*
- *Lobeliaceae*
- *Lythraceae*
- *Magnoliaceae*
- Malvaceae
- *Mimosaceae*
- *Monimiaceae*
- Octoknemaceae
- *Passifloraceae*
- *Polygonaceae*
- *Rhizophoraceae*
- *Rosaceae*
- Rubiaceae
- *Rutaceae*
- *Santalaceae*
- Sapindaceae
- Saurauiaceae
- Solanaceae
- Sterculiaceae
- *Styracaceae*
- *Theaceae*
- Tiliaceae
- *Vochysiaceae*

2-armed or T-shaped; non-glandular

- *Acanthaceae*
- *Aceraceae*
- *Amaranthaceae*
- *Ampelidaceae*
- *Araliaceae*
- Begoniaceae
- *Boraginaceae*
- *Burseraceae*
- *Caesalpiniaceae*
- *Cannabinaceae*
- *Celastraceae*
- Chenopodiaceae
- Cneoraceae
- *Combretaceae*
- **Compositae**
- Connaraceae
- **Convolvulaceae**
- *Cornaceae*
- Cruciferae
- *Ebenaceae*
- *Escalloniaceae*
- *Euphorbiaceae*
- *Ficoidaceae*
- *Flacourtiaceae*
- *Lythraceae*
- **Malpighiaceae**
- Meliaceae
- *Monimiaceae*
- *Myrtaceae*
- Papilionaceae
- Pittosporaceae
- *Proteaceae*
- Sapindaceae
- **Sapotaceae**
- *Thymelaeaceae*
- *Verbenaceae*
- *Vochysiaceae*
- Zygophyllaceae

Stellate; non-glandular or glandular

Alangiaceae
Amaranthaceae
Annonaceae
Araliaceae
Begoniaceae
Boraginaceae
Burseraceae
Caesalpiniaceae
Callitrichaceae
Capparidaceae
Caprifoliaceae
Chenopodiaceae
Cistaceae
Clethraceae
Compositae
Connaraceae
Crassulaceae
Cruciferae
Dilleniaceae
Elaeagnaceae
Ericaceae
Euphorbiaceae
Fagaceae
Ficoidaceae
Flacourtiaceae
Hamamelidaceae
Himantandraceae
Hippocrateaceae
Hydrangeaceae
Hydrophyllaceae
Hypericaceae
Juglandaceae
Loganiaceae
Loranthaceae
Malpighiaceae
Malvaceae
Melastomaceae
Meliaceae
Melianthaceae
Myristicaceae
Nyctaginaceae
Octoknemaceae
Papilionaceae
Polygonaceae
Rhamnaceae
Rosaceae
Rosaceae—Chrysobalanoideae
Rutaceae
Sapindaceae
Solanaceae
Sterculiaceae
Styracaceae
Tiliaceae
Tremandraceae
Turneraceae
Umbelliferae
Verbenaceae

Branched or dendritic; non-glandular

Acanthaceae
Amaranthaceae
Apocynaceae
Araliaceae
Bignoniaceae
Boraginaceae
Caesalpiniaceae
Capparidaceae
Caryophyllaceae
Casuarinaceae
Chenopodiaceae
Compositae
Connaraceae
Convolvulaceae
Ericaceae
Euphorbiaceae
Goodeniaceae
Guttiferae
Labiatae
Loganiaceae
Loranthaceae
Lythraceae
Melastomaceae
Mimosaceae
Myoporaceae
Myristicaceae
Myrsinaceae
Olacaceae
Opiliaceae
Papilionaceae
Platanaceae
Polemoniaceae
Portulacaceae
Primulaceae
Saurauiaceae
Scrophulariaceae
Solanaceae
Umbelliferae
Verbenaceae

Branched glandular hairs

Mimosaceae
Orobanchaceae
Platanaceae

Probably some of the families with branched non-glandular hairs also have glandular types.

Sessile or shortly stalked capitate glands

Acanthaceae
Adoxaceae
Alangiaceae
Amaranthaceae
Anacardiaceae
Asclepiadaceae
Begoniaceae
Bignoniaceae
Boraginaceae
Burseraceae
Caesalpiniaceae
Callitrichaceae
Cannabinaceae
Chenopodiaceae
Combretaceae
Compositae
Convolvulaceae
Cornaceae
Crassulaceae
Dipsacaceae
Dipterocarpaceae
Ebenaceae
Empetraceae
Escalloniaceae
Euphorbiaceae
Ficoidaceae
Frankeniaceae
Gesneriaceae
Globulariaceae
Goodeniaceae
Hernandiaceae
Humiriaceae
Julianiaceae
Labiatae
Lecythidaceae
Leitneriaceae
Lennoaceae
Lentibulariaceae
Loganiaceae
Lythraceae
Malpighiaceae
Malvaceae
Melastomaceae
Menispermaceae
Mimosaceae
Moraceae
Myoporaceae
Myricaceae
Nyssaceae
Orobanchaceae
Oxalidaceae
Papilionaceae
Passifloraceae
Pedaliaceae
Piperaceae
Plantaginaceae
Plumbaginaceae
Polygonaceae
Ranunculaceae
Rosaceae—Chrysobalanoideae
Rutaceae
Sapindaceae
Scrophulariaceae
Selaginaceae
Simarubaceae
Solanaceae
Turneraceae
Ulmaceae
Umbelliferae
Urticaceae
Vacciniaceae
Valerianaceae
Verbenaceae

Glandular capitate hairs with long or fairly long stalks

Aceraceae
Actinidiaceae
Alangiaceae
Amaranthaceae
Ampelidaceae
Anacardiaceae
Begoniaceae
Berberidaceae
Bignoniaceae
Boraginaceae
Burseraceae
Caesalpiniaceae
Cannabinaceae
Capparidaceae
Caprifoliaceae
Caricaceae
Caryophyllaceae
Chenopodiaceae
Chlaenaceae
Cistaceae
Cneoraceae
Combretaceae
Compositae
Connaraceae
Convolvulaceae
Cornaceae
Corylaceae
Crassulaceae
Cruciferae
Cucurbitaceae
Dipsacaceae
Dipterocarpaceae
Ebenaceae
Elaeocarpaceae
Elatinaceae
Empetraceae
Escalloniaceae
Euphorbiaceae
Fagaceae
Flacourtiaceae
Geraniaceae
Gesneriaceae
Goodeniaceae
Hydrophyllaceae
Juglandaceae
Labiatae
Lentibulariaceae
Loasaceae
Malesherbiaceae
Malpighiaceae
Malvaceae
Meliaceae
Menispermaceae
Mimosaceae
Monotropaceae
Moraceae
Myoporaceae
Myricaceae
Orobanchaceae
Papilionaceae
Pittosporaceae
Plantaginaceae
Polemoniaceae
Polygonaceae
Portulacaceae
Primulaceae
Ranunculaceae
Rosaceae
Rutaceae
Sabiaceae
Saxifragaceae
Scrophulariaceae
Simarubaceae
Solanaceae
Sterculiaceae
Stylidiaceae
Symplocaceae
Thelygonaceae
Tiliaceae
Tremandraceae
Turneraceae
Ulmaceae
Urticaceae
Vacciniaceae
Valerianaceae
Verbenaceae
Zygophyllaceae

Peltate hairs; glandular or non-glandular

Anacardiaceae
Ancistrocladaceae
Annonaceae
Araliaceae
Betulaceae
Bixaceae
Bombacaceae
Capparidaceae
Caprifoliaceae
Chlaenaceae
Cistaceae
Cochlospermaceae
Compositae
Convolvulaceae
Corylaceae
Datiscaceae
Dilleniaceae
Dipterocarpaceae
Elaeagnaceae
Ericaceae
Escalloniaceae
Euphorbiaceae
Fagaceae
Flacourtiaceae
Gesneriaceae
Goodeniaceae
Grossulariaceae
Himantandraceae
Hippuridaceae
Hydrophyllaceae
Icacinaceae
Juglandaceae
Malvaceae
Melastomaceae
Meliaceae
Mimosaceae
Monimiaceae
Myricaceae
Myrsinaceae
Oleaceae
Orobanchaceae
Papilionaceae
Polygonaceae
Rosaceae—Chrysobalanoideae
Rubiaceae
Salvadoraceae
Sapindaceae
Scrophulariaceae
Solanaceae
Sterculiaceae
Tiliaceae
Urticaceae
Verbenaceae

Families in which only unicellular or uniseriate hairs have been found

Akaniaceae
Aquifoliaceae
Aristolochiaceae
Balanophoraceae
Brunelliaceae
Bruniaceae
Buxaceae
Calycanthaceae
Campanulaceae
Caryocaraceae
Columelliaceae
Diapensiaceae
Dichapetalaceae
Diclidantheraceae
Epacridaceae
Eucommiaceae
Eucryphiaceae
Eupteleaceae
Garryaceae
Gonystylaceae
Goupiaceae
Grubbiaceae
Hippocastanaceae
Koeberliniaceae
Krameriaceae
Lacistemaceae
Lauraceae
Moringaceae
Myzodendraceae
Nymphaeaceae
Onagraceae
Penaeaceae
Phytolaccaceae
Podostemaceae
Polygalaceae
Resedaceae
Scytopetalaceae
Stackhousiaceae
Tamaricaceae
Trigoniaceae
Tropaeolaceae

LEAF

I. EPIDERMIS

Lower epidermis papillose

Aceraceae
Anacardiaceae
Annonaceae
Apocynaceae
Araliaceae
Aristolochiaceae
Berberidaceae
Betulaceae
Boraginaceae
Brunelliaceae
Burseraceae
Capparidaceae
Cercidiphyllaceae
Chloranthaceae
Combretaceae
Connaraceae
Cornaceae
Daphniphyllaceae
Diapensiaceae
Ebenaceae
Epacridaceae
Ericaceae
Erythroxylaceae
Euphorbiaceae
Eupteleaceae
Fagaceae
Flacourtiaceae
Geraniaceae
Guttiferae
Hernandiaceae
Icacinaceae
Lactoridaceae
Lardizabalaceae
Lauraceae
Lecythidaceae
Loganiaceae
Malpighiaceae
Melastomaceae
Menispermaceae
Mimosaceae
Myricaceae
Myristicaceae
Nyssaceae
Olacaceae
Oleaceae
Oxalidaceae
Papaveraceae
Papilionaceae
Passifloraceae
Polygalaceae
Rhamnaceae
Rosaceae
Rosaceae—Chrysobalanoideae
Santalaceae
Sapindaceae
Simarubaceae
Sonneratiaceae
Staphyleaceae
Symplocaceae
Thymelaeaceae
Ulmaceae
Vochysiaceae
Winteraceae

Upper epidermis papillose

Adoxaceae
Alangiaceae
Apocynaceae
Aristolochiaceae
Begoniaceae
Cornaceae
Euphorbiaceae
Loganiaceae
Lythraceae
Melastomaceae
Papilionaceae
Pittosporaceae
Polygonaceae
Rhamnaceae
Rubiaceae
Solanaceae
Stylidiaceae
Thelygonaceae
Umbelliferae

Both surfaces papillose

Caesalpiniaceae
Caprifoliaceae
Ericaceae
Menispermaceae
Papaveraceae
Piperaceae
Polygonaceae
Rosaceae

Papillae recorded but surface not mentioned

Acanthaceae
Aristolochiaceae
Begoniaceae
Bruniaceae
Caesalpiniaceae
Campanulaceae
Caprifoliaceae
Caryophyllaceae
Convolvulaceae
Crassulaceae
Ficoidaceae
Flacourtiaceae
Garryaceae
Gentianaceae
Hypericaceae
Krameriaceae
Labiatae
Meliaceae
Mimosaceae
Moraceae
Myoporaceae
Ochnaceae
Piperaceae
Polemoniaceae
Polygonaceae
Resedaceae
Rutaceae
Santalaceae
Tamaricaceae

Epidermis mucilaginous

Aceraceae
Anacardiaceae
Aquifoliaceae
Betulaceae
Bonnetiaceae
Burseraceae
Caesalpiniaceae
Cistaceae
Cochlospermaceae
Connaraceae
Cornaceae
Corylaceae
Crassulaceae
Cyrillaceae
Dichapetalaceae
Dipterocarpaceae
Elaeocarpaceae
Empetraceae
Ericaceae
Erythroxylaceae
Euphorbiaceae
Fagaceae
Flacourtiaceae
Fouquieraceae
Geissolomataceae
Gonystylaceae
Hamamelidaceae
Icacinaceae
Linaceae
Loganiaceae
Lythraceae
Malpighiaceae
Malvaceae
Melastomaceae
Meliaceae
Mimosaceae
Moraceae
Moringaceae
Myrtaceae
Nyssaceae
Ochnaceae
Onagraceae
Papilionaceae
Passifloraceae
Pentaphylacaceae
Phytolaccaceae
Polemoniaceae
Polygonaceae
Resedaceae
Rhamnaceae
Rhizophoraceae
Rosaceae
Rosaceae—Chrysobalanoideae
Rutaceae
Salicaceae

Sapindaceae
Sapotaceae
Schisandraceae
Simarubaceae
Staphyleaceae
Sterculiaceae
Theaceae
Thymelaeaceae
Tremandraceae
Trigoniaceae
Tropaeolaceae
Turneraceae
Ulmaceae
Violaceae
Vochysiaceae

Epidermal cells vertically divided

Connaraceae
Mimosaceae
Moraceae
Papilionaceae
Sapindaceae
Vochysiaceae

Epidermis including horizontally divided cells

Anacardiaceae
Apocynaceae
Aquifoliaceae
Bignoniaceae
Bombacaceae
Caesalpiniaceae
Celastraceae
Connaraceae
Convolvulaceae
Crassulaceae
Dichapetalaceae
Epacridaceae
Ericaceae
Globulariaceae
Goupiaceae
Guttiferae
Hernandiaceae
Hydrangeaceae
Lythraceae
Malpighiaceae
Melastomaceae
Mimosaceae
Moraceae
Passifloraceae
Pittosporaceae
Rhamnaceae
Rhizophoraceae
Salvadoraceae
Sapindaceae
Sapotaceae
Scytopetalaceae
Simarubaceae
Trigoniaceae
Ulmaceae
Vochysiaceae

II. HYPODERMIS

Hypodermis present

Acanthaceae
Alangiaceae
Anacardiaceae
Ancistrocladaceae
Apocynaceae
Aquifoliaceae
Araliaceae
Aristolochiaceae
Asclepiadaceae
Balanopsidaceae
Begoniaceae
Betulaceae
Bignoniaceae
Bombacaceae
Brunelliaceae
Burseraceae
Caesalpiniaceae
Campanulaceae
Canellaceae
Capparidaceae
Caryocaraceae
Caryophyllaceae
Celastraceae
Chenopodiaceae
Chlaenaceae
Chloranthaceae
Columelliaceae
Combretaceae
Compositae
Cornaceae
Crypteroniaceae
Cunoniaceae
Datiscaceae
Dichapetalaceae
Diclidantheraceae
Dilleniaceae
Ebenaceae
Epacridaceae
Escalloniaceae
Euphorbiaceae
Fagaceae
Flacourtiaceae
Garryaceae
Gesneriaceae
Gomortegaceae
Guttiferae
Hamamelidaceae
Hernandiaceae
Hippocrateaceae
Hydrangeaceae
Hypericaceae
Labiatae
Lardizabalaceae
Lauraceae
Lecythidaceae
Linaceae
Loganiaceae
Lythraceae
Magnoliaceae
Malvaceae
Marcgraviaceae
Medusagynaceae
Melastomaceae
Meliaceae
Menispermaceae
Monimiaceae
Moraceae
Myricaceae
Myristicaceae
Myrsinaceae
Myrtaceae
Nyctaginaceae
Ochnaceae
Olacaceae
Oleaceae
Orobanchaceae
Oxalidaceae
Papilionaceae
Passifloraceae
Pellicieraceae
Phytolaccaceae
Piperaceae
Plantaginaceae
Polemoniaceae
Polygalaceae
Polygonaceae
Portulacaceae
Proteaceae
Rhamnaceae
Rhizophoraceae
Rosaceae
Rosaceae—Chrysobalanoideae
Rubiaceae
Rutaceae
Salicaceae
Salvadoraceae
Santalaceae
Sapindaceae
Sapotaceae
Saurauiaceae
Saururaceae
Scrophulariaceae
Simarubaceae
Sterculiaceae
Symplocaceae
Tetrameristaceae
Theaceae
Thymelaeaceae
Trigoniaceae
Umbelliferae
Vacciniaceae
Verbenaceae
Violaceae
Zygophyllaceae

III. STOMATA

Ranunculaceous or anomocytic

Aceraceae
Adoxaceae
Alangiaceae
Ampelidaceae
Anacardiaceae
Apocynaceae
Aquifoliaceae
Aristolochiaceae
Asclepiadaceae
Balanopsidaceae
Berberidaceae
Betulaceae

Ranunculaceous or anomocytic (cont.)

Bixaceae
Boraginaceae
Burseraceae
Caesalpiniaceae
Calyceraceae
Campanulaceae
Canellaceae
Cannabinaceae
Capparidaceae
Caprifoliaceae
Caricaceae
Caryocaraceae
Celastraceae
Chenopodiaceae
Circaeasteraceae
Cistaceae
Clethraceae
Cneoraceae
Combretaceae
Compositae
Convolvulaceae
Cornaceae
Corylaceae
Crossosomataceae
Cucurbitaceae
Datiscaceae
Diapensiaceae
Dilleniaceae
Dipsacaceae
Ebenaceae
Elaeagnaceae
Elatinaceae
Ericaceae
Euphorbiaceae
Eupteleaceae
Fagaceae
Ficoidaceae
Fouquieraceae
Frankeniaceae
Fumariaceae
Gentianaceae
Geraniaceae
Globulariaceae
Goodeniaceae
Goupiaceae
Grubbiaceae
Haloragaceae
Hernandiaceae
Hippocrateaceae
Humiriaceae
Hydrangeaceae
Hydrophyllaceae
Hypericaceae
Icacinaceae
Juglandaceae
Julianiaceae
Labiatae
Lacistemaceae
Lardizabalaceae
Lecythidaceae
Loasaceae
Lobeliaceae
Loganiaceae
Lythraceae
Magnoliaceae
Malvaceae
Medusagynaceae
Melastomaceae
Meliaceae
Melianthaceae
Monimiaceae
Moraceae
Moringaceae
Myoporaceae
Myricaceae
Myrothamnaceae
Myrsinaceae
Myrtaceae
Nepenthaceae
Nyctaginaceae
Nymphaeaceae
Ochnaceae
Octoknemaceae
Oleaceae
Papaveraceae
Papilionaceae
Passifloraceae
Pedaliaceae
Penaeaceae
Phytolaccaceae
Plantaginaceae
Plumbaginaceae
Polemoniaceae
Polygalaceae
Polygonaceae
Primulaceae
Punicaceae
Ranunculaceae
Resedaceae
Rhamnaceae
Rhizophoraceae
Rosaceae
Sabiaceae
Sapindaceae
Sapotaceae
Saurauiaceae
Saxifragaceae
Scrophulariaceae
Selaginaceae
Simarubaceae
Solanaceae
Stachyuraceae
Stackhousiaceae
Sterculiaceae
Stylidiaceae
Styracaceae
Tamaricaceae
Tetrameristaceae
Theaceae
Thymelaeaceae
Tiliaceae
Tremandraceae
Tropaeolaceae
Turneraceae
Umbelliferae
Urticaceae
Valerianaceae
Verbenaceae
Vochysiaceae
Zygophyllaceae

Cruciferous or anisocytic

Asclepiadaceae
Caryophyllaceae
Celastraceae
Clethraceae
Compositae
Connaraceae
Convolvulaceae
Crassulaceae
Cruciferae
Diapensiaceae
Dipsacaceae
Euphorbiaceae
Flacourtiaceae
Gentianaceae—Gentianoideae
Gesneriaceae
Hypericaceae
Icacinaceae
Lecythidaceae
Loganiaceae
Melastomaceae
Moraceae
Myoporaceae
Myrsinaceae
Onagraceae
Papilionaceae
Piperaceae
Plantaginaceae
Plumbaginaceae
Rhamnaceae
Rhizophoraceae
Scrophulariaceae
Scytopetalaceae
Solanaceae
Staphyleaceae
Turneraceae
Urticaceae
Violaceae

Caryophyllaceous or diacytic

Acanthaceae
Bignoniaceae
Caryophyllaceae
Connaraceae
Globulariaceae
Labiatae
Melastomaceae
Plantaginaceae
Selaginaceae
Solanaceae
Verbenaceae

Rubiaceous or paracytic

Acanthaceae
Annonaceae
Apocynaceae
Araliaceae
Asclepiadaceae
Basellaceae
Batidaceae
Bignoniaceae
Bonnetiaceae
Byblidaceae
Caesalpiniaceae
Calycanthaceae
Canellaceae
Caprifoliaceae
Casuarinaceae
Celastraceae
Chenopodiaceae
Clethraceae
Connaraceae
Convolvulaceae

Coriariaceae
Corynocarpaceae
Cynocrambaceae
Daphniphyllaceae
Dichapetalaceae
Dilleniaceae
Dipterocarpaceae
Erythroxylaceae
Escalloniaceae
Eucryphiaceae
Euphorbiaceae
Eupomatiaceae
Ficoidaceae
Flacourtiaceae
Globulariaceae
Gomortegaceae
Goodeniaceae
Guttiferae
Hamamelidaceae
Hernandiaceae
Humiriaceae
Hydrangeaceae

Hypericaceae
Icacinaceae
Krameriaceae
Lauraceae
Linaceae
Loganiaceae
Loranthaceae
Magnoliaceae
Malpighiaceae
Melastomaceae
Menispermaceae
Mimosaceae
Monimiaceae
Myristicaceae
Myrtaceae
Nyctaginaceae
Nyssaceae
Ochnaceae
Olacaceae
Opiliaceae
Oxalidaceae
Papilionaceae

Passifloraceae
Pentaphylacaceae
Phytolaccaceae
Pittosporaceae
Plumbaginaceae
Polemoniaceae
Polygalaceae
Polygonaceae
Portulacaceae
Proteaceae
Quiinaceae
Rhamnaceae
Rhizophoraceae
Rosaceae—Chrysobalanoideae
Rubiaceae
Sabiaceae
Salicaceae
Salvadoraceae
Santalaceae
Sapindaceae

Sapotaceae
Saurauiaceae
Selaginaceae
Simarubaceae
Sonneratiaceae
Sterculiaceae
Stylidiaceae
Symplocaceae
Tamaricaceae
Tetracentraceae
Tetrameristaceae
Theaceae
Thelygonaceae
Trigoniaceae
Turneraceae
Umbelliferae
Vacciniaceae
Verbenaceae
Violaceae
Vochysiaceae
Winteraceae

Special types (for particulars see text for the family concerned)

Apocynaceae
Begoniaceae
Bignoniaceae
Buxaceae
Caesalpiniaceae
Celastraceae
Chloranthaceae

Connaraceae
Dipterocarpaceae
Elatinaceae
Gesneriaceae
Gonystylaceae
Himantandraceae
Hippocrateaceae

Krameriaceae
Menispermaceae
Moraceae
Papilionaceae
Pellicieraceae
Piperaceae
Saururaceae

Schisandraceae
Tetracentraceae
Theaceae
Thymelaeaceae
Trochodendraceae

IV. HYDATHODES

Hydathodes present (list probably incomplete)

Adoxaceae
Balsaminaceae
Begoniaceae
Campanulaceae
Caryocaraceae
Chenopodiaceae
Combretaceae
Compositae
Crassulaceae

Elaeocarpaceae
Fagaceae
Gentianaceae—Menyanthoideae
Icacinaceae
Labiatae
Limnanthaceae
Malvaceae
Menispermaceae

Moraceae
Nymphaeaceae
Orobanchaceae
Oxalidaceae
Papaveraceae
Pedaliaceae
Piperaceae
Plantaginaceae
Platanaceae

Primulaceae
Ranunculaceae
Rosaceae
Saxifragaceae
Scrophulariaceae
Stylidiaceae
Urticaceae
Valerianaceae

V. MESOPHYLL

Centric (sometimes merging with isobilateral. See next list)

Aceraceae
Alangiaceae
Ampelidaceae
Araliaceae
Bruniaceae
Campanulaceae
Capparidaceae
Caryocaraceae
Caryophyllaceae
Chenopodiaceae

Cistaceae
Combretaceae
Crassulaceae
Cruciferae
Dilleniaceae
Dipsacaceae
Ericaceae
Erythroxylaceae
Euphorbiaceae
Ficoidaceae

Flacourtiaceae
Frankeniaceae
Globulariaceae
Goodeniaceae
Guttiferae
Haloragaceae
Hippocrateaceae
Hippuridaceae
Krameriaceae
Labiatae

Lecythidaceae
Loasaceae
Lobeliaceae
Loganiaceae
Malpighiaceae
Malvaceae
Melastomaceae
Menispermaceae
Mimosaceae
Myrtaceae

Centric (*cont.*)

Ochnaceae
Olacaceae
Onagraceae
Opiliaceae
Penaeaceae
Phytolaccaceae
Pittosporaceae
Plumbaginaceae
Polygalaceae

Polygonaceae
Primulaceae
Proteaceae
Ranunculaceae
Resedaceae
Rhamnaceae
Rhizophoraceae
Rosaceae

Rubiaceae
Rutaceae
Sapindaceae
Sapotaceae
Saxifragaceae
Selaginaceae
Simarubaceae
Stackhousiaceae

Tamaricaceae
Thymelaeaceae
Ulmaceae
Umbelliferae
Vacciniaceae
Valerianaceae
Violaceae
Zygophyllaceae

Isobilateral (sometimes merging with centric. See previous list)

Acanthaceae
Alangiaceae
Amaranthaceae
Apocynaceae
Aristolochiaceae
Asclepiadaceae
Bignoniaceae
Bombacaceae
Boraginaceae
Burseraceae
Caesalpiniaceae
Campanulaceae
Capparidaceae
Caryophyllaceae
Celastraceae
Compositae
Convolvulaceae
Corylaceae
Crossosomataceae

Cruciferae
Cucurbitaceae
Dipsacaceae
Ebenaceae
Elaeagnaceae
Epacridaceae
Ericaceae
Euphorbiaceae
Fagaceae
Ficoidaceae
Frankeniaceae
Gentianaceae
Geraniaceae
Globulariaceae
Goodeniaceae
Hippuridaceae
Hydrophyllaceae
Juglandaceae
Krameriaceae

Labiatae
Lauraceae
Loganiaceae
Loranthaceae
Lythraceae
Malesherbiaceae
Malpighiaceae
Malvaceae
Mimosaceae
Moraceae
Myoporaceae
Myricaceae
Myrothamnaceae
Myrtaceae
Nyctaginaceae
Papaveraceae
Passifloraceae
Penaeaceae
Phytolaccaceae

Plantaginaceae
Platanaceae
Plumbaginaceae
Polemoniaceae
Proteaceae
Rutaceae
Salicaceae
Salvadoraceae
Santalaceae
Saxifragaceae
Scrophulariaceae
Selaginaceae
Simarubaceae
Solanaceae
Sonneratiaceae
Thymelaeaceae
Turneraceae
Verbenaceae
Vochysiaceae

Homogeneous

Anacardiaceae
Araliaceae
Aristolochiaceae
Berberidaceae
Betulaceae
Campanulaceae
Canellaceae
Capparidaceae
Caryophyllaceae
Chenopodiaceae
Compositae
Cornaceae
Cruciferae

Cyrillaceae
Diapensiaceae
Didiereaceae
Epacridaceae
Fagaceae
Flacourtiaceae
Frankeniaceae
Gentianaceae
Labiatae
Linaceae
Lythraceae
Malpighiaceae
Monimiaceae

Moraceae
Myzodendraceae
Onagraceae
Orobanchaceae
Papaveraceae
Phytolaccaceae
Plantaginaceae
Plumbaginaceae
Polygalaceae
Portulacaceae
Primulaceae
Resedaceae
Rhamnaceae

Rosaceae—Chrysobalanoideae
Rubiaceae
Santalaceae
Saxifragaceae
Simarubaceae
Sterculiaceae
Tiliaceae
Vacciniaceae
Valerianaceae
Verbenaceae

VI. VEINS

Vertically transcurrent

Aceraceae
Anacardiaceae
Ancistrocladaceae
Annonaceae
Betulaceae
Boraginaceae
Brunelliaceae

Burseraceae
Caesalpiniaceae
Capparidaceae
Celastraceae
Chlaenaceae
Clethraceae
Combretaceae

Convolvulaceae
Corylaceae
Cunoniaceae
Dipsacaceae
Dipterocarpaceae
Ebenaceae
Epacridaceae

Ericaceae
Eucryphiaceae
Euphorbiaceae
Fagaceae
Gentianaceae—Gentianoideae
Geraniaceae

Globulariaceae
Guttiferae
Hippocastanaceae
Lardizabalaceae
Lauraceae
Lythraceae
Malvaceae
Melastomaceae
Menispermaceae
Mimosaceae
Myricaceae
Myristicaceae
Nyssaceae
Ochnaceae
Papilionaceae
Platanaceae
Plumbaginaceae
Polygalaceae
Proteaceae
Rhamnaceae
Rhizophoraceae
Rosaceae
Rosaceae—Chrysobalanoideae
Sapindaceae
Sapotaceae
Selaginaceae
Simarubaceae
Styracaceae
Symplocaceae
Verbenaceae
Vochysiaceae

Sheathed by large parenchymatous cells

Amaranthaceae
Aristolochiaceae
Begoniaceae
Campanulaceae
Caryophyllaceae
Ceratophyllaceae
Compositae
Cucurbitaceae
Euphorbiaceae
Ficoidaceae
Goodeniaceae
Hippuridaceae
Labiatae
Mimosaceae
Nyctaginaceae
Polemoniaceae
Portulacaceae
Primulaceae
Punicaceae
Rosaceae
Salvadoraceae
Selaginaceae
Simarubaceae
Stylidiaceae
Thymelaeaceae
Ulmaceae
Zygophyllaceae

VII. PETIOLE

The principal types of vascular system revealed in *transverse sections through the distal end of petioles* from members of different families are shown in Fig. 1 A–I (p. xvii). The vascular system may consist of a solitary vascular strand of each of the types depicted, or it may be dissected into a large or small number of distinct strands which are, however, arranged so that they collectively present outlines of the same types A–I. The types form an intergrading series, and do not, in practice, fall into such clear-cut categories as one might be led to suppose from the figures. Nevertheless it is felt that the following lists of petiole types, and families in which they occur, may prove helpful in identification provided it is clearly understood that it has not always been easy to decide to which of the above types the vascular system conforms. In using the following lists, this fact should be constantly borne in mind and allowances for deviations and variations accordingly made. Furthermore, it should be realized that the lists refer only to the principal vascular strand or strands in the petiole, and there are, very frequently, additional, mostly smaller, strands, usually situated towards the wings or on the adaxial side of the main vascular system. Then again there are petioles with medullary bundles enclosed within the main strand. A separate list of the families in which these have been noted is given on p. 1336. There are, in addition, occasional petioles which cannot readily be placed in any of the main classes A–I. A few notes on these are given below. Finally, it must be emphasized that more than one type of petiolar vascular structure may occur in a family, so that some of the families appear in several of the following lists.

Families which exhibit special features in transverse sections through the distal end

(i) Several, often superimposed, vascular cylinders
  Salicaceae

(ii) Vascular strands sometimes centric
  Valerianaceae

(iii) An arc of or scattered bundles or steles each surrounded by an endodermis in the Haloragaceae. Steles also surrounded by an endodermis in the Acanthaceae.

(iv) Several centric and/or hemicentric bundles occur in *Alchemilla* and *Sanguisorba* amongst the Rosaceae and in species of *Saxifraga* from amongst the Saxifragaceae. Similar structure also noted in Balanopsidaceae and Salicaceae.

Vascular structure specially complex

Corylaceae
Cruciferae
Dipterocarpaceae
Juglandaceae
Melastomaceae
Myrsinaceae
Platanaceae
Proteaceae
Styracaceae

Scattered vascular bundles

Begoniaceae
Cornaceae
Gentianaceae—Menyanthoideae
Plumbaginaceae
Polygonaceae
Saxifragaceae
Umbelliferae

Medullary bundles enclosed within the main petiolar vascular system

Aceraceae
Annonaceae
Araliaceae
Begoniaceae
Berberidaceae
Bixaceae
Bombacaceae
Boraginaceae
Burseraceae
Caesalpiniaceae
Caryocaraceae
Celastraceae
Chlaenaceae
Compositae
Diapensiaceae
Dipterocarpaceae
Elaeocarpaceae
Escalloniaceae
Euphorbiaceae
Fagaceae
Geraniaceae
Goupiaceae
Guttiferae
Hamamelidaceae
Hippocastanaceae
Hippocrateaceae
Hydrangeaceae
Hydrophyllaceae
Loasaceae
Magnoliaceae
Meliaceae
Melianthaceae
Mimosaceae
Moraceae
Nepenthaceae
Nyctaginaceae
Ochnaceae
Oxalidaceae
Piperaceae
Polygalaceae
Proteaceae
Quiinaceae
Ranunculaceae
Rhizophoraceae
Rosaceae—Chrysobalanoideae
Rubiaceae
Rutaceae
Sapindaceae
Sapotaceae
Saurauiaceae
Scrophulariaceae
Simarubaceae
Sterculiaceae
Tiliaceae
Umbelliferae
Urticaceae
Verbenaceae

A single, median crescentic vascular strand of types A–D (Fig. 1, p. xvii)

(Types approximating to E may also be present in some of these families.)
(Additional vascular strands, especially in the wings of the petiole, occur in many but by no means all of the species examined.)

Acanthaceae
Alangiaceae
Apocynaceae
Aquifoliaceae
Asclepiadaceae
Basellaceae
Betulaceae
Boraginaceae
Buxaceae
Calycanthaceae
Campanulaceae
Canellaceae
Caprifoliaceae
Celastraceae
Cistaceae
Combretaceae
Convolvulaceae
Coriariaceae
Cornaceae
Cruciferae
Ebenaceae
Elaeagnaceae
Ericaceae
Erythroxylaceae
Escalloniaceae
Eucommiaceae
Euphorbiaceae
Flacourtiaceae
Garryaceae
Geraniaceae
Guttiferae
Hydrangeaceae
Hydrophyllaceae
Hypericaceae
Icacinaceae
Krameriaceae
Labiatae
Lauraceae
Linaceae
Loasaceae
Lobeliaceae
Loganiaceae
Lythraceae
Malvaceae
Marcgraviaceae
Monimiaceae
Moraceae
Myoporaceae
Myricaceae
Myrsinaceae
Myrtaceae
Ochnaceae
Olacaceae
Oleaceae
Onagraceae
Papilionaceae
Pentaphylacaceae
Pittosporaceae
Polemoniaceae
Portulacaceae
Primulaceae
Punicaceae
Resedaceae
Rhamnaceae
Rhizophoraceae
Rosaceae
Rubiaceae
Rutaceae
Santalaceae
Sapotaceae
Salvadoraceae
Schisandraceae
Scrophulariaceae
Simarubaceae
Solanaceae
Stachyuraceae
Theaceae
Thymelaeaceae
Tiliaceae
Tremandraceae
Turneraceae
Ulmaceae
Vacciniaceae
Verbenaceae
Violaceae

An arc of separate bundles shaped like A–D (Fig. 1, p. xvii)

(Arcs of separate bundles approximating in structure to type E may also be present in some of these families.)

Acanthaceae
Alangiaceae
Amaranthaceae
Annonaceae
Araliaceae
Aristolochiaceae
Balsaminaceae
Basellaceae

Berberidaceae
Boraginaceae
Burseraceae
Cannabinaceae
Capparidaceae
Caprifoliaceae
Chenopodiaceae
Chloranthaceae
Cistaceae
Compositae
Cornaceae
Corynocarpaceae
Crassulaceae
Crossosomataceae
Cruciferae
Cucurbitaceae
Dipsacaceae
Droseraceae
Epacridaceae
Euphorbiaceae
Eupomatiaceae
Flacourtiaceae
Gentianaceae
Globulariaceae
Hamamelidaceae
Hippocrateaceae
Hydrangeaceae
Labiatae
Lauraceae
Lecythidaceae
Loganiaceae
Loranthaceae
Medusagynaceae
Melastomaceae
Meliaceae
Monimiaceae
Moraceae
Myrsinaceae
Nyctaginaceae
Olacaceae
Papaveraceae
Papilionaceae
Phytolaccaceae
Piperaceae
Pittosporaceae
Plantaginaceae
Polygonaceae
Primulaceae
Proteaceae
Ranunculaceae
Resedaceae
Rhamnaceae
Rosaceae
Rutaceae
Saururaceae
Saxifragaceae
Schisandraceae
Scrophulariaceae
Scytopetalaceae
Solanaceae
Thelygonaceae
Tremandraceae
Trochodendraceae
Turneraceae
Ulmaceae
Umbelliferae
Urticaceae
Valerianaceae
Winteraceae

A solitary vascular strand of type E (Fig. 1, p. xvii)

Betulaceae
Corylaceae

A closed cylindrical strand of type F (Fig. 1, p. xvii)

(This type intergrades with that shown in G. Additional strands in the wings or in the medullary position also occur in certain species.)

Acanthaceae
Anacardiaceae
Bombacaceae
Bignoniaceae
Burseraceae
Caesalpiniaceae
Caryocaraceae
Chlaenaceae
Cochlospermaceae
Corylaceae
Dilleniaceae
Ericaceae
Euphorbiaceae
Eupteleaceae
Fagaceae
Flacourtiaceae
Guttiferae
Hamamelidaceae
Hippocastanaceae
Hydrophyllaceae
Juglandaceae
Krameriaceae
Malvaceae
Meliaceae
Mimosaceae
Moraceae
Ochnaceae
Oxalidaceae
Papilionaceae
Polygalaceae
Primulaceae
Rosaceae—Chrysobalanoideae
Rubiaceae
Rutaceae
Salicaceae
Sapindaceae
Simarubaceae
Sterculiaceae
Theaceae
Thymelaeaceae
Tiliaceae
Turneraceae
Ulmaceae
Vacciniaceae
Zygophyllaceae

A cylindrical vascular strand of type F (Fig. 1, p. xvii) but dissected

(This type merges into the dissected form of G.)

Acanthaceae
Ampelidaceae
Anacardiaceae
Araliaceae
Aristolochiaceae
Begoniaceae
Berberidaceae
Bignoniaceae
Bixaceae
Burseraceae
Caricaceae
Celastraceae
Chenopodiaceae
Cucurbitaceae
Diapensiaceae
Elaeocarpaceae
Euphorbiaceae
Fagaceae
Gentianaceae—Menyanthoideae
Geraniaceae
Goupiaceae
Hamamelidaceae
Himantandraceae
Hippocrateaceae
Julianiaceae
Lardizabalaceae
Magnoliaceae
Malvaceae
Meliaceae
Melianthaceae
Menispermaceae
Mimosaceae
Nepenthaceae
Ochnaceae
Oxalidaceae
Papilionaceae
Passifloraceae
Pellicieraceae
Piperaceae
Proteaceae
Quiinaceae
Ranunculaceae
Rhizophoraceae
Rutaceae
Sapindaceae
Sapotaceae
Simarubaceae
Staphyleaceae
Sterculiaceae
Tropaeolaceae
Umbelliferae
Verbenaceae
Zygophyllaceae

A closed, cylindrical, flattened or concave vascular strand (Fig. 1 G, p. xvii)

(This type merges into the continuous form of F.)

Acanthaceae
Bignoniaceae
Bonnetiaceae
Boraginaceae
Brunelliaceae
Campanulaceae
Caprifoliaceae
Celastraceae
Combretaceae
Cunoniaceae
Cyrillaceae
Daphniphyllaceae
Elaeagnaceae
Ericaceae
Fagaceae
Flacourtiaceae
Lobeliaceae
Marcgraviaceae
Mimosaceae
Oleaceae
Rosaceae—Chrysobalanoideae
Rubiaceae
Sabiaceae
Sapotaceae
Styracaceae
Symplocaceae

A flattened or concave vascular strand (Fig. 1 G) dissected into separate bundles

(This type sometimes merges into the dissected form of F.)

Aceraceae
Akaniaceae
Amaranthaceae
Anacardiaceae
Berberidaceae
Bignoniaceae
Brunelliaceae
Chenopodiaceae
Compositae
Eucryphiaceae
Fagaceae
Hippocrateaceae
Labiatae
Loasaceae
Nyctaginaceae
Oleaceae
Papilionaceae
Polygonaceae
Ranunculaceae

A solitary arc-shaped vascular strand with very much incurved ends (Fig. 1 H)

(This type, which merges into those shown in A–D, is often accompanied by accessory vascular strands especially in the wings.)

Actinidiaceae
Apocynaceae
Aquifoliaceae
Bonnetiaceae
Boraginaceae
Campanulaceae
Cannabinaceae
Celastraceae
Cercidiphyllaceae
Clethraceae
Cneoraceae
Combretaceae
Ebenaceae
Elaeagnaceae
Escalloniaceae
Euphorbiaceae
Fagaceae
Flacourtiaceae
Grossulariaceae
Guttiferae
Hamamelidaceae
Hydrophyllaceae
Krameriaceae
Labiatae
Marcgraviaceae
Meliaceae
Moraceae
Myrtaceae
Nyssaceae
Oleaceae
Papilionaceae
Polemoniaceae
Polygalaceae
Rubiaceae
Salvadoraceae
Santalaceae
Sapotaceae
Saurauiaceae
Scrophulariaceae
Sterculiaceae
Styracaceae
Tetracentraceae
Theaceae
Thymelaeaceae
Tiliaceae
Verbenaceae

An arc-shaped vascular system with incurved ends (Fig. 1 H), but dissected

Acanthaceae
Capparidaceae
Cucurbitaceae
Ebenaceae
Euphorbiaceae
Fagaceae
Flacourtiaceae
Labiatae
Papilionaceae
Scrophulariaceae
Violaceae

Vascular system composed of an abaxial arc with a separate adaxial strand between the ends (Fig. 1 I) (List probably incomplete)

Caesalpiniaceae
Cornaceae
Cunoniaceae
Dilleniaceae
Euphorbiaceae
Hippocrateaceae
Hydrangeaceae
Leitneriaceae
Mimosaceae
Rubiaceae
Sapotaceae
Turneraceae

Vascular system composed of an abaxial arc of separate bundles with several adaxial strands between the ends of the arc; as Fig. 1 I but dissected

Caesalpiniaceae
Cornaceae
Diapensiaceae
Euphorbiaceae
Gesneriaceae
Moraceae
Nyssaceae
Pedaliaceae

STEM

I. CORK

Superficial

Acanthaceae
Aceraceae
Achariaceae
Actinidiaceae
Akaniaceae
Amaranthaceae
Ampelidaceae
Anacardiaceae
Ancistrocladaceae
Annonaceae
Apocynaceae
Aquifoliaceae
Araliaceae
Aristolochiaceae
Asclepiadaceae
Balanopsidaceae
Basellaceae
Begoniaceae
Berberidaceae
Betulaceae
Bignoniaceae
Bombacaceae
Bonnetiaceae
Boraginaceae
Bruniaceae
Burseraceae
Buxaceae
Cactaceae
Caesalpiniaceae
Calycanthaceae
Campanulaceae
Canellaceae
Cannabinaceae
Capparidaceae
Caprifoliaceae
Caryocaraceae
Celastraceae
Cercidiphyllaceae
Chenopodiaceae
Cistaceae
Combretaceae
Compositae
Connaraceae
Convolvulaceae
Cornaceae
Coriariaceae
Corylaceae
Corynocarpaceae
Crassulaceae
Crossosomataceae
Cucurbitaceae
Cunoniaceae
Daphniphyllaceae
Datiscaceae
Diapensiaceae
Dichapetalaceae
Diclidantheraceae
Dilleniaceae
Dipsacaceae
Dipterocarpaceae
Ebenaceae
Elaeagnaceae
Elaeocarpaceae
Erythroxylaceae
Escalloniaceae
Eucommiaceae
Euphorbiaceae
Fagaceae
Flacourtiaceae
Fouquieraceae
Garryaceae
Geissolomataceae
Geraniaceae
Gesneriaceae
Gomortegaceae
Gonystylaceae
Goodeniaceae
Grubbiaceae
Guttiferae
Hamamelidaceae
Hernandiaceae
Himantandraceae
Hippocrateaceae
Humiriaceae
Hydrophyllaceae
Icacinaceae
Juglandaceae
Julianiaceae
Labiatae
Lacistemaceae
Lardizabalaceae
Lauraceae
Lecythidaceae
Leitneriaceae
Lobeliaceae
Loganiaceae
Loranthaceae
Magnoliaceae
Malesherbiaceae
Malpighiaceae
Malvaceae
Marcgraviaceae
Medusagynaceae
Melastomaceae
Meliaceae
Menispermaceae
Mimosaceae
Monimiaceae
Moraceae
Myoporaceae
Myricaceae
Myristicaceae
Myrsinaceae
Myrtaceae
Nyctaginaceae
Nyssaceae
Ochnaceae
Octoknemaceae
Olacaceae
Oleaceae
Oliniaceae
Opiliaceae
Oxalidaceae
Papilionaceae
Passifloraceae
Pedaliaceae
Pellicieraceae
Pentaphylacaceae
Phytolaccaceae
Piperaceae
Pittosporaceae
Plantaginaceae
Platanaceae
Plumbaginaceae
Polemoniaceae
Polygonaceae
Primulaceae
Proteaceae
Rhamnaceae
Rhizophoraceae
Rosaceae
Rosaceae—Chrysobalanoideae
Rubiaceae
Rutaceae
Sabiaceae
Salicaceae
Salvadoraceae
Santalaceae
Sapindaceae
Sapotaceae
Saurauiaceae
Saxifragaceae
Scytopetalaceae
Selaginaceae
Simarubaceae
Solanaceae
Sonneratiaceae
Stachyuraceae
Staphyleaceae
Sterculiaceae
Symplocaceae
Tamaricaceae
Tetracentraceae
Theaceae
Thymelaeaceae
Tiliaceae
Trigoniaceae
Trochodendraceae
Turneraceae
Ulmaceae
Umbelliferae
Urticaceae
Vacciniaceae
Verbenaceae
Vochysiaceae
Winteraceae
Zygophyllaceae

Deep seated

Acanthaceae
Aceraceae
Actinidiaceae
Ampelidaceae
Anacardiaceae
Ancistrocladaceae
Apocynaceae
Batidaceae
Berberidaceae
Bignoniaceae
Boraginaceae
Burseraceae
Buxaceae
Campanulaceae
Caprifoliaceae
Caryophyllaceae
Casuarinaceae
Celastraceae
Chenopodiaceae
Cistaceae
Clethraceae
Columelliaceae
Combretaceae
Compositae
Convolvulaceae
Crassulaceae
Cruciferae
Cucurbitaceae
Cyrillaceae
Diapensiaceae
Dilleniaceae
Dipsacaceae

Deep seated (cont.)

Ebenaceae
Empetraceae
Epacridaceae
Ericaceae
Escalloniaceae
Euphorbiaceae
Eupteleaceae
Ficoidaceae
Fouquieraceae
Frankeniaceae
Gesneriaceae
Goodeniaceae
Grossulariaceae
Hydrangeaceae
Hypericaceae
Koeberliniaceae
Krameriaceae
Labiatae
Lauraceae
Loasaceae
Loganiaceae
Lythraceae
Malpighiaceae
Melastomaceae
Melianthaceae
Menispermaceae
Myrtaceae
Nepenthaceae
Nyctaginaceae
Oleaceae
Onagraceae
Papilionaceae
Penaeaceae
Plantaginaceae
Polemoniaceae
Polygonaceae
Primulaceae
Proteaceae
Punicaceae
Ranunculaceae
Rosaceae
Rubiaceae
Sapindaceae
Sargentodoxaceae
Saxifragaceae
Scrophulariaceae
Selaginaceae
Solanaceae
Styracaceae
Tamaricaceae
Tetrameristaceae
Theaceae
Tropaeolaceae
Umbelliferae
Urticaceae
Vacciniaceae
Valerianaceae
Verbenaceae
Vochysiaceae
Zygophyllaceae

II. LITTLE OR NO SCLERENCHYMA IN THE PERICYCLIC REGION

Acanthaceae
Apocynaceae
Araliaceae
Balsaminaceae
Begoniaceae
Boraginaceae
Cactaceae
Campanulaceae
Clethraceae
Convolvulaceae
Cornaceae
Cyrillaceae
Dipsacaceae
Ericaceae
Euphorbiaceae
Ficoidaceae
Grossulariaceae
Hydrangeaceae
Hydrophyllaceae
Labiatae
Lobeliaceae
Loganiaceae
Lythraceae
Malpighiaceae
Nymphaeaceae
Pittosporaceae
Plantaginaceae
Portulacaceae
Primulaceae
Rubiaceae
Salicaceae
Saxifragaceae
Scrophulariaceae
Selaginaceae
Stackhousiaceae
Turneraceae
Umbelliferae
Valerianceae
Verbenaceae

III. WIDTH OF PRIMARY MEDULLARY RAYS

Broad

Acanthaceae (steles)
Aceraceae
Adoxaceae
Akaniaceae
Amaranthaceae
Ampelidaceae
Apocynaceae
Aquifoliaceae
Araliaceae
Aristolochiaceae
Asclepiadaceae
Balanophoraceae (rhizome)
Balsaminaceae
Basellaceae
Batidaceae
Begoniaceae
Berberidaceae
Bignoniaceae
Byblidaceae
Cactaceae
Caesalpiniaceae
Calyceraceae
Caricaceae
Caryophyllaceae
Casuarinaceae
Celastraceae
Chenopodiaceae
Compositae
Coriariaceae
Corynocarpaceae
Cruciferae
Cucurbitaceae
Didiereaceae
Dilleniaceae
Droseraceae (scape)
Euphorbiaceae
Eupomatiaceae
Fagaceae
Ficoidaceae
Garryaceae
Gentianaceae—Menyanthoideae
Geraniaceae
Goodeniaceae
Grossulariaceae
Haloragaceae (steles)
Hydrangeaceae
Hydrophyllaceae
Hydrostachyaceae
Icacinaceae
Koeberliniaceae
Labiatae
Lardizabalaceae
Lauraceae
Lecythidaceae
Lennoaceae
Limnanthaceae
Loasaceae
Loganiaceae
Loranthaceae
Magnoliaceae
Medusagynaceae
Melianthaceae
Menispermaceae
Mimosaceae
Monimiaceae
Monotropaceae
Moraceae
Myricaceae
Myrsinaceae
Myzodendraceae
Nyctaginaceae
Nymphaeaceae (steles)
Orobanchaceae
Oxalidaceae
Papaveraceae
Papilionaceae
Phytolaccaceae
Piperaceae
Plantaginaceae
Platanaceae
Plumbaginaceae
Polygonaceae
Portulacaceae
Primulaceae
Proteaceae
Ranunculaceae
Rhizophoraceae
Rosaceae
Sabiaceae
Salvadoraceae
Sargentodoxaceae
Saururaceae
Saxifragaceae
Solanaceae
Tamaricaceae
Tropaeolaceae
Ulmaceae
Umbelliferae
Urticaceae
Valerianaceae
Verbenaceae
Violaceae
Zygophyllaceae

Narrow

Acanthaceae
Aceraceae
Actinidiaceae
Alangiaceae
Anacardiaceae
Apocynaceae
Asclepiadaceae
Balanopsidaceae
Bignoniaceae
Bixaceae
Bonnetiaceae
Boraginaceae
Brunelliaceae
Bruniaceae
Burseraceae
Buxaceae
Caesalpiniaceae
Calycanthaceae
Campanulaceae
Canellaceae
Cannabinaceae
Capparidaceae
Caprifoliaceae
Caryocaraceae
Caryophyllaceae
Casuarinaceae
Celastraceae
Cercidiphyllaceae
Chlaenaceae
Cistaceae
Clethraceae
Cneoraceae
Combretaceae
Compositae
Connaraceae
Convolvulaceae
Cornaceae
Corylaceae
Crassulaceae
Crossosomataceae
Cruciferae
Crypteroniaceae
Cunoniaceae
Daphniphyllaceae
Datiscaceae
Diapensiaceae
Diclidantheraceae
Dipsacaceae
Ebenaceae
Elaeocarpaceae
Elaeagnaceae
Empetraceae
Epacridaceae
Ericaceae
Erythroxylaceae
Escalloniaceae
Eucommiaceae
Eucryphiaceae
Euphorbiaceae
Fagaceae
Flacourtiaceae
Frankeniaceae
Geissolomataceae
Gentianaceae—Gentianoideae
Geraniaceae
Gesneriaceae
Globulariaceae
Gomortegaceae
Gonystylaceae
Goodeniaceae
Grossulariaceae
Grubbiaceae
Guttiferae
Haloragaceae
Hamamelidaceae
Hippocastanaceae
Hydrangeaceae
Hydrophyllaceae
Hypericaceae
Juglandaceae
Krameriaceae
Labiatae
Lacistemaceae
Lauraceae
Lecythidaceae
Leitneriaceae
Linaceae
Loasaceae
Lobeliaceae
Loganiaceae
Loranthaceae
Lythraceae
Malesherbiaceae
Malpighiaceae
Marcgraviaceae
Melastomaceae
Meliaceae
Melianthaceae
Mimosaceae
Monimiaceae
Monotropaceae
Moringaceae
Myoporaceae
Myricaceae
Myristicaceae
Myrothamnaceae
Myrsinaceae
Myrtaceae
Nepenthaceae
Nyssaceae
Ochnaceae
Octoknemaceae
Oleaceae
Oliniaceae
Onagraceae
Oxalidaceae
Papilionaceae
Passifloraceae
Pedaliaceae
Pellicieraceae
Penaeaceae
Pentaphylacaceae
Plantaginaceae
Polemoniaceae
Polygalaceae
Polygonaceae
Portulacaceae
Primulaceae
Punicaceae
Quiinaceae
Resedaceae
Rhamnaceae
Rhizophoraceae
Rosaceae
Rosaceae—Chrysobalanoideae
Rubiaceae
Rutaceae
Salicaceae
Santalaceae
Sapindaceae
Sapotaceae
Schisandraceae
Scrophulariaceae
Scytopetalaceae
Selaginaceae
Simarubaceae
Solanaceae
Sonneratiaceae
Stachyuraceae
Stackhousiaceae
Staphyleaceae
Styracaceae
Symplocaceae
Tetrameristaceae
Theaceae
Thelygonaceae
Thymelaeaceae
Tremandraceae
Turneraceae
Urticaceae
Vacciniaceae
Valerianaceae
Verbenaceae
Violaceae
Winteraceae
Zygophyllaceae

Narrow and broad mixed

Anacardiaceae
Annonaceae
Araliaceae
Begoniaceae
Betulaceae
Bombacaceae
Boraginaceae
Cannabinaceae
Caryophyllaceae
Chloranthaceae
Crassulaceae
Cruciferae
Dipterocarpaceae
Elaeagnaceae
Eupteleaceae
Hernandiaceae
Himantandraceae
Hydrophyllaceae
Icacinaceae
Lactoridaceae
Loasaceae
Loranthaceae
Malvaceae
Moraceae
Orobanchaceae
Passifloraceae
Pedaliaceae
Pittosporaceae
Primulaceae
Sabiaceae
Saurauiaceae
Saxifragaceae
Scytopetalaceae
Simarubaceae
Solanaceae
Staphyleaceae
Sterculiaceae
Tetracentraceae
Tiliaceae
Trigoniaceae
Trochodendraceae
Ulmaceae

IV. VESSELS

Perforation plates scalariform (see also list under 'Wood' on p. 1349)

Achariaceae
Actinidiaceae
Akaniaceae
Alangiaceae
Anacardiaceae
Apocynaceae
Aquifoliaceae
Araliaceae
Balanopsidaceae
Begoniaceae
Berberidaceae
Betulaceae
Bonnetiaceae
Brunelliaceae
Bruniaceae
Buxaceae
Byblidaceae
Campanulaceae
Canellaceae
Caprifoliaceae
Casuarinaceae
Celastraceae
Cercidiphyllaceae
Chenopodiaceae
Chloranthaceae
Clethraceae
Columelliaceae
Compositae
Cornaceae
Corylaceae
Cunoniaceae
Cyrillaceae
Daphniphyllaceae
Diapensiaceae
Dichapetalaceae
Dilleniaceae
Dipsacaceae
Elaeocarpaceae
Empetraceae
Epacridaceae
Ericaceae
Escalloniaceae
Eucommiaceae
Eucryphiaceae
Euphorbiaceae
Eupteleaceae
Fagaceae
Flacourtiaceae
Garryaceae
Geissolomataceae
Gentianaceae—Menyanthoideae
Gomortegaceae
Goupiaceae
Grossulariaceae
Grubbiaceae
Hamamelidaceae
Hernandiaceae
Himantandraceae
Hippocastanaceae
Hippocrateaceae
Humiriaceae
Hydrangeaceae
Icacinaceae
Juglandaceae
Julianiaceae
Labiatae
Lacistemaceae
Lardizabalaceae
Lauraceae
Lobeliaceae
Loganiaceae
Magnoliaceae
Malesherbiaceae
Monimiaceae
Myricaceae
Myristicaceae
Myrothamnaceae
Myrsinaceae
Nyssaceae
Ochnaceae
Octoknemaceae
Olacaceae
Oleaceae
Passifloraceae
Pentaphylacaceae
Piperaceae
Platanaceae
Polemoniaceae
Ranunculaceae
Rhamnaceae
Rhizophoraceae
Rubiaceae
Sabiaceae
Sapotaceae
Sarraceniaceae
Saururaceae
Schisandraceae
Scytopetalaceae
Stachyuraceae
Staphyleaceae
Styracaceae
Symplocaceae
Tetrameristaceae
Theaceae
Tremandraceae
Umbelliferae
Vacciniaceae
Valerianaceae
Verbenaceae
Violaceae

V. DIAPHRAGMS IN PITH

Annonaceae
Dilleniaceae
Himantandraceae
Juglandaceae
Magnoliaceae
Nymphaeaceae
Theaceae

VI. CORTICAL BUNDLES

Araliaceae
Begoniaceae
Berberidaceae (rhizome)
Bombacaceae
Buxaceae
Cactaceae
Calycanthaceae (pericycle)
Campanulaceae
Capparidaceae (pericycle and phloem)
Casuarinaceae
Compositae
Cornaceae
Crassulaceae
Cruciferae
Cucurbitaceae
Dipterocarpaceae
Erythroxylaceae
Euphorbiaceae
Ficoidaceae
Gentianaceae—Menyanthoideae
Gesneriaceae
Lecythidaceae
Lennoaceae
Loganiaceae
Melastomaceae
Nepenthaceae
Ochnaceae
Oleaceae
Papilionaceae
Plumbaginaceae
Polygonaceae
Proteaceae
Rutaceae
Saxifragaceae
Scytopetalaceae
Turneraceae
Umbelliferae

VII. MEDULLARY BUNDLES

Acanthaceae
Amaranthaceae
Araliaceae
Begoniaceae
Bignoniaceae
Burseraceae
Cactaceae
Campanulaceae
Chenopodiaceae
Compositae
Convolvulaceae
Crassulaceae
Cruciferae
Euphorbiaceae
Gentianaceae—Gentianoideae
Gesneriaceae
Goodeniaceae
Icacinaceae
Loganiaceae
Melastomaceae
Melianthaceae
Mimosaceae
Myzodendraceae

- Nepenthaceae
- Nyctaginaceae
- Ochnaceae
- Orobanchaceae
- Papilionaceae
- Plantaginaceae
- *Plumbaginaceae*
- *Polygonaceae*
- *Ranunculaceae*
- Saxifragaceae
- *Sterculiaceae*
- *Trigoniaceae*
- Umbelliferae
- *Verbenaceae*

VIII. INTRAXYLARY (MEDULLARY) PHLOEM

- *Acanthaceae*
- **Apocynaceae**
- **Asclepiadaceae**
- Basellaceae
- Combretaceae
- Compositae
- **Convolvulaceae**
- **Crypteroniaceae**
- **Cucurbitaceae**
- *Euphorbiaceae*
- Gentianaceae—Gentianoideae
- Loganiaceae
- **Lythraceae**
- **Melastomaceae**
- *Myristicaceae*
- **Myrtaceae**
- Oliniaceae
- **Onagraceae**
- **Penaeaceae**
- *Polygonaceae*
- *Portulacaceae*
- **Punicaceae**
- **Solanaceae**
- Sonneratiaceae
- **Thymelaeaceae**
- *Verbenaceae*
- *Vochysiaceae*

IX. ANOMALOUS STRUCTURE

Divided or compound xylem

- Acanthaceae
- Apocynaceae
- *Asclepiadaceae*
- Bignoniaceae
- Boraginaceae
- Caesalpiniaceae
- Compositae
- Convolvulaceae
- Icacinaceae
- *Papilionaceae*
- Rubiaceae
- Sapindaceae
- *Thymelaeaceae*
- *Umbelliferae*
- *Verbenaceae*

Interxylary (*included*) *phloem* (*in stems or roots*) (see also list under 'Wood' on p. 1352)

- *Acanthaceae*
- Apocynaceae
- *Asclepiadaceae*
- Caryocaraceae
- Chenopodiaceae
- Combretaceae
- Convolvulaceae
- *Cucurbitaceae*
- *Euphorbiaceae*
- Gentianaceae—Gentianoideae
- *Hippocrateaceae*
- Icacinaceae
- *Loranthaceae*
- *Malpighiaceae*
- *Melastomaceae*
- *Mimosaceae*
- *Nyctaginaceae*
- *Onagraceae*
- *Papilionaceae*
- *Phytolaccaceae*
- *Plumbaginaceae*
- *Salvadoraceae*
- *Solanaceae*
- *Thymelaeaceae*

Secondary thickening from successive cambia (cf. concentric type, p. 1353)

- **Amaranthaceae**
- Ampelidaceae
- *Asclepiadaceae*
- Bignoniaceae
- *Buxaceae*
- Caesalpiniaceae
- Capparidaceae
- Caryophyllaceae
- **Chenopodiaceae**
- Compositae
- Convolvulaceae
- *Crassulaceae*
- *Cruciferae*
- *Cucurbitaceae*
- *Dilleniaceae*
- Ficoidaceae
- *Hippocrateaceae*
- Icacinaceae
- *Loranthaceae*
- **Menispermaceae**
- **Nyctaginaceae**
- *Papilionaceae*
- Phytolaccaceae
- *Polygalaceae*
- Rubiaceae
- Thymelaeaceae
- *Umbelliferae*
- *Verbenaceae*

CRYSTALS, CYSTOLITHS, AND CRISTARQUE CELLS

I. CRYSTALS

Solitary crystals

- Acanthaceae
- Aceraceae
- *Akaniaceae*
- *Alangiaceae*
- *Amaranthaceae*
- Ampelidaceae
- *Anacardiaceae*
- Ancistrocladaceae
- Annonaceae
- Apocynaceae
- Aquifoliaceae
- *Araliaceae*
- Aristolochiaceae
- Asclepiadaceae
- *Balanophoraceae*
- *Basellaceae*
- Batidaceae
- Begoniaceae
- Berberidaceae
- Betulaceae
- *Bignoniaceae*
- Bombacaceae
- *Boraginaceae*
- Brunelliaceae
- Bruniaceae
- Burseraceae
- Buxaceae
- Caesalpiniaceae
- *Canellaceae*
- *Cannabinaceae*
- Capparidaceae
- Caprifoliaceae
- Caryocaraceae
- *Caryophyllaceae*
- Casuarinaceae
- Celastraceae
- *Chenopodiaceae*
- *Chloranthaceae*
- *Clethraceae*
- *Cneoraceae*

Solitary crystals (cont.)

Cochlospermaceae
Columelliaceae
Combretaceae
Compositae
Connaraceae
Convolvulaceae
Cornaceae
Coriariaceae
Corylaceae
Corynocarpaceae
Crassulaceae
Cruciferae
Cucurbitaceae
Cunoniaceae
Cyrillaceae
Datiscaceae
Diapensiaceae
Diclidantheraceae
Dilleniaceae
Dipterocarpaceae
Ebenaceae
Elaeagnaceae
Elaeocarpaceae
Epacridaceae
Ericaceae
Erythroxylaceae
Escalloniaceae
Eucryphiaceae
Euphorbiaceae
Fagaceae
Ficoidaceae
Flacourtiaceae
Fouquieraceae
Geissolomataceae
Geraniaceae
Gesneriaceae
Globulariaceae
Gomortegaceae
Gonystylaceae
Goodeniaceae
Grubbiaceae
Guttiferae
Haloragaceae
Hamamelidaceae
Hernandiaceae
Himantandraceae
Hippocastanaceae
Hippocrateaceae
Humiriaceae
Hypericaceae
Icacinaceae
Juglandaceae
Julianiaceae
Koeberliniaceae
Labiatae
Lardizabalaceae
Lauraceae
Lecythidaceae
Linaceae
Loganiaceae
Loranthaceae
Lythraceae
Magnoliaceae
Malpighiaceae
Malvaceae
Medusagynaceae
Meliaceae
Menispermaceae
Mimosaceae
Monimiaceae
Moraceae
Myoporaceae
Myricaceae
Myrsinaceae
Myrtaceae
Nyssaceae
Ochnaceae
Octoknemaceae
Olacaceae
Oleaceae
Oxalidaceae
Papilionaceae
Passifloraceae
Pedaliaceae
Pellicieraceae
Pentaphylacaceae
Phytolaccaceae
Piperaceae
Pittosporaceae
Platanaceae
Podostemaceae
Polygalaceae
Polygonaceae
Portulacaceae
Proteaceae
Punicaceae
Ranunculaceae
Rhamnaceae
Rhizophoraceae
Rosaceae
Rubiaceae
Rutaceae
Salicaceae
Salvadoraceae
Santalaceae
Sapindaceae
Sapotaceae
Scrophulariaceae
Selaginaceae
Simarubaceae
Solanaceae
Staphyleaceae
Sterculiaceae
Styracaceae
Symplocaceae
Tamaricaceae
Tetracentraceae
Theaceae
Thymelaeaceae
Tiliaceae
Tremandraceae
Trigoniaceae
Trochodendraceae
Ulmaceae
Umbelliferae
Urticaceae
Vaccinaceae
Verbenaceae
Violaceae
Vochysiaceae
Winteraceae
Zygophyllaceae

Cluster crystals

Aceraceae
Akaniaceae
Alangiaceae
Amaranthaceae
Ampelidaceae
Anacardiaceae
Ancistrocladaceae
Annonaceae
Apocynaceae
Aquifoliaceae
Araliaceae
Aristolochiaceae
Asclepiadaceae
Balanophoraceae
Balanopsidaceae
Basellaceae
Batidaceae
Begoniaceae
Berberidaceae
Betulaceae
Bignoniaceae
Bixaceae
Bombacaceae
Bonnetiaceae
Boraginaceae
Brunelliaceae
Bruniaceae
Burseraceae
Buxaceae
Cactaceae
Caesalpiniaceae
Calyceraceae
Campanulaceae
Canellaceae
Cannabinaceae
Capparidaceae
Caprifoliaceae
Caricaceae
Caryocaraceae
Caryophyllaceae
Casuarinaceae
Celastraceae
Cercidiphyllaceae
Chenopodiaceae
Chlaenaceae
Chloranthaceae
Cistaceae
Clethraceae
Columelliaceae
Combretaceae
Compositae
Convolvulaceae
Coriariaceae
Cornaceae
Corylaceae
Corynocarpaceae
Crassulaceae
Crypteroniaceae
Cucurbitaceae
Cunoniaceae
Cyrillaceae
Daphniphyllaceae
Diapensiaceae
Didiereaceae
Dipsacaceae
Dipterocarpaceae
Ebenaceae
Elaeocarpaceae
Elatinaceae
Empetraceae
Epacridaceae
Ericaceae
Escalloniaceae
Eucryphiaceae
Euphorbiaceae
Eupomatiaceae
Eupteleaceae
Fagaceae
Ficoidaceae
Flacourtiaceae
Frankeniaceae
Geissolomataceae
Gentianaceae—Gentianoideae
Geraniaceae
Gesneriaceae
Gonystylaceae
Goodeniaceae
Goupiaceae
Grossulariaceae
Grubbiaceae
Guttiferae

Haloragaceae
Hamamelidaceae
Hedystachyaceae
Himantandraceae
Hippocastanaceae
Hippocrateaceae
Humiriaceae
Hydrangeaceae
Hydrophyllaceae
Hydrostachyaceae
Hypericaceae
Icacinaceae
Juglandaceae
Julianiaceae
Krameriaceae
Labiatae
Lacistemaceae
Lardizabalaceae
Lecythidaceae
Leitneriaceae
Linaceae
Loganiaceae
Loranthaceae
Lythraceae
Malpighiaceae
Malvaceae
Medusagynaceae
Melastomaceae
Meliaceae
Melianthaceae
Menispermaceae
Mimosaceae
Moraceae
Moringaceae
Myoporaceae
Myricaceae
Myristicaceae
Myrothamnaceae
Myrsinaceae
Myrtaceae
Nepenthaceae
Nyctaginaceae
Nymphaeaceae
Nyssaceae
Ochnaceae
Olacaceae
Onagraceae
Papaveraceae
Papilionaceae
Passifloraceae
Pedaliaceae
Penaeaceae
Phytolaccaceae
Piperaceae
Pittosporaceae
Platanaceae
Plumbaginaceae
Polygalaceae
Polygonaceae
Portulacaceae
Proteaceae
Punicaceae
Quiinaceae
Ranunculaceae
Rhamnaceae
Rhizophoraceae
Rosaceae
Rosaceae—Chrysobalanoideae
Rubiaceae
Rutaceae
Sabiaceae
Salicaceae
Salvadoraceae
Santalaceae
Sapindaceae
Sapotaceae
Saururaceae
Saxifragaceae
Scrophulariaceae
Simarubaceae
Solanaceae
Stachyuraceae
Staphyleaceae
Sterculiaceae
Styracaceae
Symplocaceae
Tamaricaceae
Tetracentraceae
Theaceae
Thymelaeaceae
Tiliaceae
Tremandraceae
Trigoniaceae
Turneraceae
Ulmaceae
Umbelliferae
Urticaceae
Vacciniaceae
Violaceae
Vochysiaceae
Zygophyllaceae

Styloids

Apocynaceae
Columelliaceae
Escalloniaceae
Euphorbiaceae
Ficoidaceae
Geraniaceae
Loganiaceae
Malpighiaceae
Melastomaceae
Melianthaceae
Menispermaceae
Mimosaceae
Nyctaginaceae
Onagraceae
Papilionaceae
Phytolaccaceae
Pittosporaceae
Rosaceae
Rutaceae
Sapindaceae
Saurauiaceae
Simarubaceae
Thymelaeaceae
Tiliaceae
Ulmaceae
Urticaceae
Zygophyllaceae

Raphides (not always distinguished from acicular crystals, see next list), (see also list under 'Wood' on p. 1354)

Acanthaceae
Actinidiaceae
Ampelidaceae
Balsaminaceae
Cactaceae
Combretaceae
Compositae
Dilleniaceae
Ficoidaceae
Hydrangeaceae
Marcgraviaceae
Melianthaceae
Menispermaceae
Monimiaceae
Nyctaginaceae
Onagraceae
Pedaliaceae
Pellicieraceae
Phytolaccaceae
Rubiaceae
Rutaceae
Saurauiaceae
Urticaceae
Tetrameristaceae
Thelygonaceae
Zygophyllaceae

Acicular crystals (not always distinguished from raphides, see previous list)

Acanthaceae
Ampelidaceae
Aristolochiaceae
Bignoniaceae
Boraginaceae
Campanulaceae
Compositae
Convolvulaceae
Coriariaceae
Crossosomataceae
Datiscaceae
Elaeagnaceae
Gentianaceae—Gentianoideae
Gesneriaceae
Globulariaceae
Gomortegaceae
Haloragaceae
Hernandiaceae
Labiatae
Lauraceae
Lobeliaceae
Loganiaceae
Lythraceae
Menispermaceae
Monimiaceae
Myoporaceae
Myristicaceae
Myrsinaceae
Oleaceae
Papilionaceae
Piperaceae
Rhamnaceae
Rubiaceae
Scrophulariaceae
Selaginaceae
Umbelliferae
Verbenaceae
Zygophyllaceae

Crystal-sand

Actinidiaceae
Amaranthaceae
Araliaceae
Boraginaceae
Buxaceae
Caprifoliaceae
Caryophyllaceae
Celastraceae
Chenopodiaceae
Cornaceae
Crassulaceae
Cucurbitaceae
Dilleniaceae
Elaeagnaceae
Escalloniaceae
Ficoidaceae
Garryaceae
Gentianaceae—
  Gentianoideae
Icacinaceae
Krameriaceae
Loganiaceae
Menispermaceae
Myrtaceae
Nyctaginaceae
Oxalidaceae
Piperaceae
Polygonaceae
Portulacaceae
Rubiaceae
Rutaceae
Sapindaceae
Sapotaceae
Solanaceae
Tetrameristaceae
Thymelaeaceae
Umbelliferae

Sphaerocrystals (list probably incomplete)

Aceraceae
Asclepiadaceae
Bignoniaceae
Cactaceae
Campanulaceae
Cannabinaceae
Clethraceae
Compositae
Crassulaceae
Empetraceae
Euphorbiaceae
Ficoidaceae
Krameriaceae
Labiatae
Loranthaceae
Oleaceae
Papilionaceae
Phytolaccaceae
Santalaceae

Crystalline masses (particularly in material preserved in alcohol)

Aceraceae
Balanophoraceae
Basellaceae
Cactaceae
Capparidaceae
Chloranthaceae
Epacridaceae
Gentianaceae—
  Gentianoideae
Geraniaceae
Lythraceae
Menispermaceae
Moraceae
Nepenthaceae
Papilionaceae
Rubiaceae
Theaceae
Valerianaceae
Verbenaceae
Violaceae
Zygophyllaceae

II. BERBERIN PRESENT

Berberidaceae
Menispermaceae
Papaveraceae
Ranunculaceae

III. CYSTOLITHS

Acanthaceae
Begoniaceae
Boraginaceae
Campanulaceae
Cannabinaceae
Cistaceae
Cucurbitaceae
Flacourtiaceae
Hernandiaceae
Loasaceae
Moraceae
Opiliaceae
Scrophulariaceae
Ulmaceae
Urticaceae

IV. CRISTARQUE CELLS

Melastomaceae
Ochnaceae
Scytopetalaceae

INTERNAL SECRETORY STRUCTURES

SECRETED material is commonly deposited in cells, cavities, or canals which possess diagnostic value because of their restricted occurrence. The secretory structures are usually further classified according to the chemical nature of their contents, and this procedure has been adopted in drawing up the following lists. Thus 'myrosin cells', 'laticiferous canals', and so on are listed separately. It must, however, be remembered that many of these terms are applied rather loosely to secretory structures having contents of which the chemical identity has been established by surmise or rather inadequate investigation. Then again there can be little doubt that many secretory structures contain a mixture of substances. For instance the same cells may contain resinous and tanniniferous substances or oil and mucilage. The following lists have been compiled because of the proved taxonomic value of secretory structures, but it must always be remembered, when using them, that the precise nature of their contents has been accurately determined in only a few plants.

I. CELLS

Cells with unspecified contents

Akaniaceae
Amaranthaceae
Ampelidaceae
Anacardiaceae
Ancistrocladaceae
Annonaceae
Aristolochiaceae
Asclepiadaceae
Betulaceae
Bixaceae
Boraginaceae
Buxaceae
Caesalpiniaceae
Calycanthaceae
Canellaceae
Caprifoliaceae
Celastraceae
Chloranthaceae
Clethraceae
Cneoraceae
Cochlospermaceae
Combretaceae
Compositae
Cornaceae
Corylaceae
Crassulaceae
Cruciferae
Cunoniaceae
Dichapetalaceae
Didiereaceae
Dipsacaceae
Elatinaceae
Erythroxylaceae
Escalloniaceae
Euphorbiaceae
Eupomatiaceae
Eupteleaceae
Fagaceae
Flacourtiaceae
Fumariaceae
Garryaceae
Gomortegaceae
Grossulariaceae
Guttiferae
Hamamelidaceae
Himantandraceae
Hydrangeaceae
Hypericaceae
Juglandaceae
Koeberliniaceae
Krameriaceae
Labiatae
Lactoridaceae
Lythraceae
Magnoliaceae
Malpighiaceae
Melastomaceae
Meliaceae
Mimosaceae
Monimiaceae
Myricaceae
Myristicaceae
Myrsinaceae
Ochnaceae
Opiliaceae
Papilionaceae
Piperaceae
Platanaceae
Plumbaginaceae
Podostemaceae
Primulaceae
Punicaceae
Quiinaceae
Rhamnaceae
Rubiaceae
Rutaceae
Sabiaceae
Salicaceae
Sapindaceae
Sapotaceae
Saurauiaceae
Saururaceae
Saxifragaceae
Simarubaceae
Sonneratiaceae
Stackhousiaceae
Staphyleaceae
Styracaceae
Tetracentraceae
Thymelaeaceae
Tremandraceae
Trochodendraceae
Tropaeolaceae
Verbenaceae
Violaceae
Winteraceae

Cells with laticiferous contents

Apocynaceae
Compositae
Convolvulaceae
Eucommiaceae
Euphorbiaceae
Fumariaceae
Myrtaceae
Papaveraceae

Cells with mucilaginous contents (see also list under 'Wood' on p. 1354)

Ampelidaceae
Annonaceae
Basellaceae
Bombacaceae
Burseraceae
Cactaceae
Caesalpiniaceae
Chlaenaceae
Cochlospermaceae
Cunoniaceae
Dichapetalaceae
Didiereaceae
Dipterocarpaceae
Elaeocarpaceae
Gentianaceae—Gentianoideae
Gonystylaceae
Hamamelidaceae
Hernandiaceae
Lauraceae
Magnoliaceae
Malvaceae
Marcgraviaceae
Medusagynaceae
Moraceae
Nepenthaceae
Opiliaceae
Pentaphylacaceae
Portulacaceae
Resedaceae
Rhamnaceae
Rosaceae
Rubiaceae
Schisandraceae
Simarubaceae
Sterculiaceae
Tiliaceae
Ulmaceae
Urticaceae
Vochysiaceae

Cells containing myrosin

Capparidaceae
Cruciferae
Moringaceae
Resedaceae
Tropaeolaceae

Cells with oily contents (see also list under 'Wood' on p. 1354)

Calycanthaceae
Hernandiaceae
Lauraceae
Magnoliaceae
Onagraceae
Rhizophoraceae
Simarubaceae
Winteraceae

Cells with resiniferous contents

Bruniaceae
Cochlospermaceae
Euphorbiaceae
Gomortegaceae
Marcgraviaceae
Meliaceae
Rubiaceae
Rutaceae
Schisandraceae
Tetracentraceae

Cells with tanniniferous contents

Ampelidaceae
Anacardiaceae
Annonaceae
Asclepiadaceae
Bruniaceae
Caesalpiniaceae
Caryocaraceae
Celastraceae
Cephalotaceae
Ceratophyllaceae
Convolvulaceae
Crassulaceae
Cunoniaceae
Daphniphyllaceae
Diapensiaceae
Didiereaceae
Ebenaceae
Elaeagnaceae
Epacridaceae
Ericaceae
Escalloniaceae
Eucryphiaceae
Euphorbiaceae
Grossulariaceae
Hamamelidaceae
Hippocrateaceae
Lacistemaceae
Lecythidaceae
Leitneriaceae
Limnanthaceae
Loranthaceae
Melastomaceae
Mimosaceae
Monotropaceae
Moraceae
Myricaceae
Myrsinaceae
Myrtaceae
Nepenthaceae
Nyctaginaceae
Papilionaceae
Passifloraceae
Phytolaccaceae
Plumbaginaceae
Polygonaceae
Proteaceae
Rhamnaceae
Rhizophoraceae
Rosaceae
Rutaceae
Santalaceae
Sapindaceae
Sargentodoxaceae
Saxifragaceae
Scrophulariaceae
Stackhousiaceae
Sterculiaceae
Symplocaceae
Tamaricaceae
Thelygonaceae
Turneraceae
Vacciniaceae
Vochysiaceae

II. SACS OR CAVITIES

Sacs or cavities with unspecified contents

Aceraceae
Araliaceae
Bombacaceae
Caesalpiniaceae
Combretaceae
Compositae
Connaraceae
Euphorbiaceae
Eupomatiaceae
Flacourtiaceae
Gonystylaceae
Hippocrateaceae
Hydrangeaceae
Hypericaceae
Lythraceae
Meliaceae
Menispermaceae
Mimosaceae
Myoporaceae
Myrsinaceae
Myrtaceae
Olacaceae
Oxalidaceae
Papilionaceae
Podostemaceae
Polemoniaceae
Polygalaceae
Polygonaceae
Primulaceae
Proteaceae
Quiinaceae
Rhamnaceae
Rosaceae—Chrysobalanoideae
Rubiaceae
Rutaceae
Schisandraceae
Scrophulariaceae
Styracaceae
Umbelliferae

Cavities with mucilaginous contents

Bombacaceae
Chenopodiaceae
Didiereaceae
Dipterocarpaceae
Euphorbiaceae
Icacinaceae
Malvaceae
Ochnaceae
Rhamnaceae
Rubiaceae
Schisandraceae
Simarubaceae
Sterculiaceae
Tiliaceae
Ulmaceae
Zygophyllaceae

Cavities with tanniniferous contents

Balsaminaceae
Boraginaceae
Caesalpiniaceae
Caprifoliaceae
Euphorbiaceae
Ficoidaceae
Krameriaceae
Lactoridaceae
Monimiaceae
Myristicaceae
Papilionaceae
Passifloraceae
Solanaceae
Vacciniaceae

III. CANALS

(See also lists under 'Wood' on p. 1353)

Canals with unspecified contents

Araliaceae
Berberidaceae
Bixaceae
Burseraceae
Caryocaraceae
Cornaceae
Gesneriaceae
Guttiferae
Hernandiaceae
Hypericaceae
Koeberliniaceae
Leitneriaceae
Loranthaceae
Marcgraviaceae
Myrsinaceae
Papilionaceae
Pittosporaceae
Podostemaceae
Rhizophoraceae
Rutaceae
Simarubaceae
Umbelliferae
Urticaceae

Canals with laticiferous contents

Apocynaceae
Asclepiadaceae
Cactaceae
Campanulaceae
Cannabinaceae
Caricaceae
Compositae
Convolvulaceae
Eucommiaceae
Euphorbiaceae
Flacourtiaceae
Hippocrateaceae
Icacinaceae
Lobeliaceae
Moraceae
Nymphaeaceae
Olacaceae
Oleaceae
Papaveraceae
Urticaceae

Canals with mucilaginous contents

Chloranthaceae
Cistaceae
Cochlospermaceae
Combretaceae
Icacinaceae
Lecythidaceae
Loranthaceae
Malvaceae
Moraceae
Piperaceae
Rosaceae
Sterculiaceae
Tiliaceae
Urticaceae
Vochysiaceae

Canals with resiniferous contents

Anacardiaceae
Compositae
Dipterocarpaceae
Julianiaceae

WOOD

THE inclusion of a family in a list signifies only that the feature sometimes occurs in the family, and not that it occurs in every genus. Where the feature occurs only seldom the family name has been printed in italics.

I. VESSELS

Scalariform perforation plates (see also list on p. 1342)

Actinidiaceae
Akaniaceae
Alangiaceae
Anacardiaceae
Apocynaceae
Aquifoliaceae
Araliaceae
Berberidaceae
Betulaceae
Brunelliaceae
Buxaceae
Canellaceae
Caprifoliaceae
Caryocaraceae
Casuarinaceae
Celastraceae
Cercidiphyllaceae
Chenopodiaceae
Chloranthaceae
Clethraceae
Compositae
Cornaceae
Corylaceae
Cunoniaceae
Cyrillaceae
Daphniphyllaceae
Dichapetalaceae
Dilleniaceae
Elaeocarpaceae
Empetraceae
Epacridaceae
Ericaceae
Erythroxylaceae
Escalloniaceae
Eucryphiaceae
Euphorbiaceae 'A'
Eupomatiaceae
Eupteleaceae
Fagaceae
Flacourtiaceae
Fouquieraceae
Garryaceae
Geraniaceae
Goupiaceae
Grossulariaceae
Guttiferae 'A'
Hamamelidaceae
Hernandiaceae
Himantandraceae
Hippocastanaceae
Humiriaceae
Hydrangeaceae
Hypericaceae
Icacinaceae
Juglandaceae
Labiatae
Lacistemaceae
Lardizabalaceae
Lauraceae
Lecythidaceae
Linaceae
Loganiaceae
Magnoliaceae
Marcgraviaceae
Melianthaceae
Monimiaceae
Myricaceae
Myristicaceae
Myrothamnaceae
Myrsinaceae
Myrtaceae
Nyssaceae
Ochnaceae
Octoknemaceae
Olacaceae
Oleaceae
Passifloraceae
Pentaphylacaceae
Piperaceae
Platanaceae
Proteaceae
Ranunculaceae
Rhamnaceae
Rhizophoraceae
Rubiaceae
Sabiaceae
Sapotaceae
Saurauiaceae
Schisandraceae
Scytopetalaceae
Stachyuraceae
Staphyleaceae
Styracaceae
Symplocaceae
Theaceae
Tremandraceae
Turneraceae
Umbelliferae
Vacciniaceae
Valerianaceae
Verbenaceae
Violaceae

Spiral thickening

Acanthaceae
Aceraceae
Actinidiaceae
Anacardiaceae
Annonaceae
Apocynaceae
Aquifoliaceae
Araliaceae
Aristolochiaceae
Berberidaceae
Bignoniaceae
Boraginaceae

Spiral thickening (_cont._)

Buxaceae
Caesalpiniaceae
Calycanthaceae
Capparidaceae
Caprifoliaceae
Casuarinaceae
Celastraceae
Cercidiphyllaceae
Chenopodiaceae
Cistaceae
Clethraceae
Compositae
Connaraceae
Cornaceae
Corylaceae
Corynocarpaceae
Elaeagnaceae
Elaeocarpaceae
Epacridaceae
Ericaceae
Escalloniaceae
Eucommiaceae
Eucryphiaceae
Euphorbiaceae
Fagaceae
Flacourtiaceae
Garryaceae
Geraniaceae
Hamamelidaceae
Himantandraceae
Hippocastanaceae
Hydrangeaceae
Hypericaceae
Icacinaceae
Juglandaceae
Koeberliniaceae
Labiatae
Lardizabalaceae
Lecythidaceae
Leitneriaceae
Linaceae
Loganiaceae
Loranthaceae
Magnoliaceae
Malpighiaceae
Malvaceae
Meliaceae
Mimosaceae
Monimiaceae
Moraceae
Myrsinaceae
Myrtaceae
Oleaceae
Oxalidaceae
Papaveraceae
Papilionaceae
Pentaphylacaceae
Phytolaccaceae
Pittosporaceae
Polygalaceae
Polygonaceae
Proteaceae
Ranunculaceae
Rhamnaceae
Rosaceae
Rubiaceae
Rutaceae
Santalaceae
Sapindaceae
Sapotaceae
Saurauiaceae
Schisandraceae
Scrophulariaceae
Simarubaceae
Solanaceae
Stachyuraceae
Staphyleaceae
Sterculiaceae
Symplocaceae
Theaceae
Thymelaeaceae
Tiliaceae
Tremandraceae
Turneraceae
Ulmaceae
Urticaceae
Vacciniaceae
Verbenaceae
Violaceae

Vestured pits (from Bailey, 78)

Apocynaceae
Asclepiadaceae
Capparidaceae
Combretaceae
Cruciferae
Crypteroniaceae
Dipterocarpaceae
Euphorbiaceae
Leguminosae
Loganiaceae
Lythraceae
Malpighiaceae
Melastomaceae
Myrtaceae
Ochnaceae
Oleaceae
Oliniaceae
Onagraceae
Polygonaceae
Punicaceae
Rubiaceae
Sonneratiaceae
Thymelaeaceae
Vochysiaceae

Ring-porous (Families marked * not more than semi-ring-porous)

_Acanthaceae_*
_Alangiaceae_*
Ampelidaceae
Anacardiaceae
Annonaceae
Apocynaceae*
Aquifoliaceae
Araliaceae
Aristolochiaceae
Asclepiadaceae
Berberidaceae
Bignoniaceae
Boraginaceae
_Cactaceae_*
Caesalpiniaceae
Calycanthaceae
Caprifoliaceae
Celastraceae
_Chenopodiaceae_*
_Cistaceae_*
Cneoraceae
Combretaceae
Compositae
_Connaraceae_*
Coriariaceae
_Cornaceae_*
Corylaceae*
Crossosomataceae
Cunoniaceae*
Dilleniaceae
_Ebenaceae_*
Elaeagnaceae
_Elaeocarpaceae_*
Empetraceae*
Ericaceae
_Escalloniaceae_*
Eucommiaceae*
_Eucryphiaceae_*
Euphorbiaceae—
Crotonoideae
Fagaceae
Fouquieraceae
Geraniaceae
Grossulariaceae
Hydrangeaceae
_Hydrophyllaceae_*
Juglandaceae
Koeberliniaceae
Labiatae*
Lauraceae
Leitneriaceae*
Loganiaceae*
Lythraceae
Malpighiaceae
Malvaceae
Meliaceae
Mimosaceae*
Moraceae
Myricaceae*
_Myrsinaceae_*
Oleaceae
_Papaveraceae_*
Papilionaceae
_Passifloraceae_*
Polygonaceae
Proteaceae
Ranunculaceae
Rhamnaceae
Rosaceae
Rubiaceae
Rutaceae
Santalaceae
Sapindaceae
_Sapotaceae_*
_Scrophulariaceae_*
Simarubaceae
Solanaceae
_Staphyleaceae_*
Sterculiaceae
Styracaceae*
Tamaricaceae
Theaceae*
Thymelaeaceae*
_Tiliaceae_*
Ulmaceae
Verbenaceae
_Violaceae_*
_Zygophyllaceae_*

Dendritic pattern

Annonaceae
Araliaceae
Asclepiadaceae
Berberidaceae
Boraginaceae
Caesalpiniaceae
Calycanthaceae
Cneoraceae
Fagaceae
Leitneriaceae
Loganiaceae
Melastomaceae
Moraceae
Oleaceae
Papilionaceae
Rhamnaceae
Rosaceae
Rutaceae
Sapotaceae
Solanaceae
Thymelaeaceae
Ulmaceae

II. VESSELS ABSENT

Tetracentraceae
Trochodendraceae
Winteraceae

III. VASICENTRIC TRACHEIDS

Apocynaceae
Asclepiadaceae
Bonnetiaceae
Boraginaceae
Calycanthaceae
Casuarinaceae
Celastraceae
Combretaceae
Compositae
Connaraceae
Dipterocarpaceae
Fagaceae
Goupiaceae
Grossulariaceae
Guttiferae 'B'
Hypericaceae
Lauraceae
Linaceae
Myrtaceae
Ochnaceae
Olacaceae
Oleaceae
Polygalaceae
Proteaceae
Quiinaceae
Rutaceae
Sapotaceae
Simarubaceae
Santalaceae
Staphyleaceae
Thymelaeaceae
Zygophyllaceae

IV. FIBRES

With distinctly bordered pits

Actinidiaceae
Annonaceae
Apocynaceae
Aquifoliaceae
Betulaceae
Bonnetiaceae
Buxaceae
Canellaceae
Capparidaceae
Caprifoliaceae
Casuarinaceae
Celastraceae
Cercidiphyllaceae
Chloranthaceae
Cistaceae
Clethraceae
Compositae
Cornaceae
Crossosomataceae
Crypteroniaceae
Cunoniaceae
Cyrillaceae
Daphniphyllaceae
Diclidantheraceae
Dilleniaceae
Dipterocarpaceae
Ebenaceae
Elaeagnaceae
Epacridaceae
Ericaceae
Erythroxylaceae
Escalloniaceae
Eucommiaceae
Eucryphiaceae
Euphorbiaceae
Fagaceae
Garryaceae
Goupiaceae
Guttiferae
Hamamelidaceae
Hippocastanaceae
Hippocrateaceae
Humiriaceae
Hypericaceae
Icacinaceae
Koeberliniaceae
Lardizabalaceae
Lecythidaceae
Linaceae
Loranthaceae
Melastomaceae
Menispermaceae
Monimiaceae
Moraceae
Myricaceae
Myrtaceae
Nyssaceae
Octoknemaceae
Olacaceae
Oleaceae
Opiliaceae
Passifloraceae
Pentaphylacaceae
Polygalaceae
Proteaceae
Quiinaceae
Ranunculaceae
Rhizophoraceae
Rosaceae—Chrysobalanoideae
Rubiaceae
Sabiaceae
Santalaceae
Sapotaceae
Saurauiaceae
Schisandraceae
Solanaceae
Stachyuraceae
Staphyleaceae
Symplocaceae
Tetracentraceae (tracheids)
Theaceae
Thymelaeaceae
Trigoniaceae
Trochodendraceae (tracheids)
Turneraceae
Vacciniaceae
Winteraceae (tracheids)
Zygophyllaceae

Septate

Acanthaceae
Akaniaceae
Ampelidaceae
Anacardiaceae
Apocynaceae
Araliaceae
Berberidaceae
Bignoniaceae
Boraginaceae
Brunelliaceae
Burseraceae
Cactaceae
Caesalpiniaceae
Campanulaceae
Capparidaceae
Caprifoliaceae
Caryocaraceae
Celastraceae
Combretaceae
Compositae
Connaraceae
Cunoniaceae
Datiscaceae
Elaeocarpaceae
Epacridaceae
Ericaceae
Euphorbiaceae 'B'
Eupomatiaceae
Flacourtiaceae
Geraniaceae
Gesneriaceae
Grossulariaceae

Septate (*cont.*)

Guttiferae 'A'
Hernandiaceae
Hippocrateaceae
Hydrangeaceae
Hypericaceae
Juglandaceae
Julianiaceae
Labiatae
Lacistemaceae
Lardizabalaceae
Lauraceae
Lecythidaceae
Loganiaceae
Lythraceae
Magnoliaceae
Malpighiaceae
Marcgraviaceae
Melastomaceae
Meliaceae
Melianthaceae
Mimosaceae
Monimiaceae
Moraceae
Myristicaceae
Myrsinaceae
Myrtaceae
Ochnaceae
Olacaceae
Oleaceae
Oliniaceae
Onagraceae
Oxalidaceae
Papilionaceae
Passifloraceae
Phytolaccaceae
Piperaceae
Pittosporaceae
Plumbaginaceae
Polygonaceae
Punicaceae
Rhamnaceae
Rhizophoraceae
Rosaceae
Rubiaceae
Rutaceae
Sabiaceae
Sapindaceae
Sapotaceae
Scrophulariaceae
Simarubaceae
Solanaceae
Sonneratiaceae
Staphyleaceae
Trigoniaceae
Urticaceae
Vacciniaceae
Verbenaceae
Violaceae
Vochysiaceae

Spiral thickening

Aquifoliaceae
Aristolochiaceae
Boraginaceae
Buxaceae
Caprifoliaceae
Celastraceae
Compositae
Cornaceae
Elaeagnaceae
Epacridaceae
Ericaceae
Eucommiaceae
Garryaceae
Hamamelidaceae
Hydrangeaceae
Koeberliniaceae
Marcgraviaceae
Nyssaceae
Oleaceae
Proteaceae
Rosaceae
Scrophulariaceae
Stachyuraceae
Symplocaceae
Tremandraceae
Vacciniaceae

V. STORIED STRUCTURE

Rays storied

Ampelidaceae
Asclepiadaceae
Bignoniaceae
Bixaceae
Bombacaceae
Boraginaceae
Burseraceae
Caesalpiniaceae
Cochlospermaceae
Compositae
Ebenaceae
Elaeagnaceae
Hippocastanaceae
Malvaceae
Meliaceae
Moraceae
Moringaceae
Myoporaceae
Papilionaceae
Rutaceae
Salvadoraceae
Sapindaceae
Sterculiaceae
Thymelaeaceae
Tiliaceae
Ulmaceae
Verbenaceae
Zygophyllaceae

Parenchyma or fibres storied

Amaranthaceae
Ampelidaceae
Annonaceae
Asclepiadaceae
Berberidaceae
Bignoniaceae
Bixaceae
Bombacaceae
Boraginaceae
Burseraceae
Caesalpiniaceae
Capparidaceae
Chenopodiaceae
Cneoraceae
Cochlospermaceae
Compositae
Coriariaceae
Corynocarpaceae
Datiscaceae
Ebenaceae
Elaeagnaceae
Elaeocarpaceae
Gesneriaceae
Hippocastanaceae
Lardizabalaceae
Lauraceae
Loranthaceae
Malvaceae
Meliaceae
Melianthaceae
Mimosaceae
Moraceae
Moringaceae
Myoporaceae
Myrsinaceae
Nyctaginaceae
Olacaceae
Papilionaceae
Piperaceae
Polygonaceae
Ranunculaceae
Rhamnaceae
Rutaceae
Salvadoraceae
Simarubaceae
Sterculiaceae
Tamaricaceae
Thymelaeaceae
Tiliaceae
Ulmaceae
Urticaceae
Zygophyllaceae

VI. INCLUDED (INTERXYLARY) PHLOEM

(See also lists on p. 1343)

Foraminate type

Amaranthaceae
Apocynaceae
Asclepiadaceae
Chenopodiaceae
Combretaceae
Guttiferae
Hippocrateaceae
Icacinaceae

- Loganiaceae
- Melastomaceae
- Nyctaginaceae
- Onagraceae
- Salvadoraceae
- Thymelaeaceae
- Vochysiaceae

Concentric type

- Amaranthaceae
- Buxaceae
- Caesalpiniaceae
- Capparidaceae
- Chenopodiaceae
- Connaraceae
- Convolvulaceae
- Dilleniaceae
- Hippocrateaceae
- Menispermaceae
- Nyctaginaceae
- Papilionaceae
- Phytolaccaceae
- Plumbaginaceae
- Polygalaceae
- Rutaceae
- Verbenaceae

VII. INTERCELLULAR CANALS

(See also lists on pp. 1348–9)

Normal vertical canals

- Caesalpiniaceae
  - *Copaifera*
  - *Daniella*
  - *Detarium*
  - *Eperua*
  - *Gossweilerodendron*
  - *Kingiodendron*
- Caesalpiniaceae
  - *Oxystigma*
  - *Prioria*
  - *Pterygopodium*
  - *Sindora*
- Connaraceae
  - *Connarus*
- Cornaceae
  - *Mastixia*
- Dipterocarpaceae
  - All genera except *Marquesia* and *Monotes*
- Simarubaceae
  - *Simaruba* and possibly other genera

Traumatic vertical canals

- Ampelidaceae
- Bombacaceae
- Boraginaceae
- Burseraceae
- Caesalpiniaceae
- Combretaceae
- Elaeagnaceae
- Elaeocarpaceae
- Euphorbiaceae
- Hamamelidaceae
- Lecythidaceae
- Malvaceae
- Meliaceae
- Mimosaceae
- Moringaceae
- Myrtaceae
- Papilionaceae
- Proteaceae
- Rosaceae
- Rutaceae
- Sapindaceae
- Simarubaceae
- Sterculiaceae
- Styracaceae
- Vochysiaceae

Radial canals

- Anacardiaceae
  - *Antrocaryon*
  - *Astronium*
  - *Buchanania*
  - *Campnosperma*
  - *Euroschinus*
  - *Gluta*
  - *Harpephyllum*
  - *Koordersiodendron*
  - *Lannea*
  - *Loxopterygium*
  - *Malosma*
  - *Melanochyla*
  - *Melanorrhoea*
  - *Metopium*
  - *Microstemon*
  - *Odina*
  - *Parishia*
  - *Pentaspadon*
  - *Pistacia*
  - *Pleiogynium*
  - *Poupartia*
  - *Pseudospondias*
  - *Rhodosphaera*
  - *Rhus*
  - *Schinopsis*
- Anacardiaceae
  - *Schinus*
  - *Sclerocarya*
  - *Schmalzia*
  - *Smodingium*
  - *Spondias*
  - *Swintonia*
  - *Tapiria*
  - *Trichoscypha*
- Apocynaceae
  - *Alstonia*
  - *Ambelania*
  - *Aspidosperma*
  - *Bonafousia*
  - *Couma*
  - *Dyera*
  - *Funtumia*
  - *Himatanthus*
  - *Lacmellia*
  - *Macoubea*
  - *Malouetia*
  - *Microplumeria* (?)
  - *Neocouma*
  - *Parahancornia*
  - *Peschiera*
- Apocynaceae
  - *Plumeria*
  - *Rauwolfia*
  - *Stemmadenia*
  - *Stenosolen*
  - *Tabernaemontana*
  - *Thevetia*
  - *Vallesia*
  - *Zschokkea*
- Araliaceae
  - *Acanthopanax*
  - *Arthrophyllum*
  - *Brassaia*
  - *Cheirodendron*
  - *Cussonia*
  - *Dendropanax*
  - *Didymopanax*
  - *Dizygotheca*
  - *Gilibertia*
  - *Heptapleurum*
  - *Heteropanax*
  - *Myodocarpus*
  - *Nothopanax*
  - *Oreopanax*
  - *Panax*
- Araliaceae
  - *Schefflera*
  - *Sciadodendron*
  - *Textoria*
  - *Tieghemopanax*
- Burseraceae
  - *Boswellia*
  - *Bursera*
  - *Canariellum*
  - *Canarium*
  - *Commiphora*
  - *Dacryodes*
  - *Elaphrium*
  - *Garuga*
  - *Protium*
  - *Tetragastris*
  - *Triomma*
- Cactaceae
- Cochlospermaceae
  - *Cochlospermum*
- Compositae
  - *Artemisia*
  - *Chrysothamnus*
  - *Hymenoclea*

***Radial canals* (*cont.*)**

- Crypteroniaceae
  - *Crypteronia*
- Dipterocarpaceae
  - *Balanocarpus*
  - *Shorea*
  - *Vateria*
- Euphorbiaceae
  - *Alchornea*
  - *Baloghia*
  - *Cunuria*
  - *Euphorbia*
  - *Hippomane*
  - *Homalanthus*
  - *Nealchornea*
  - *Sebastiania*
- Guttiferae, Group B
  - *Mammea*
  - *Rheedia*
- Hamamelidaceae
  - *Altingia*
- Julianiaceae
  - *Juliania*
  - *Orthopterygium*
- Loganiaceae
  - *Anthocleista*
- Moraceae
  - *Acanthosphaera*
  - *Anonocarpus*
  - *Antiaris*
  - *Artocarpus*
  - *Bagassa*
  - *Bosquiea*
  - *Brosimopsis*
  - *Brosimum*
  - *Castilla*
  - *Chlorophora*
  - *Ficus*
  - *Gymnartocarpus*
  - *Helicostylis*
  - *Naucleopsis*
- Moraceae
  - *Noyera*
  - *Ogcodeia*
  - *Olmedia*
  - *Olmedioperebea*
  - *Olmediophaena*
  - *Parartocarpus*
  - *Perebea*
  - *Prainea*
  - *Pseudolmedia*
  - *Sloetia*
  - *Trophis*
  - *Trymatococcus*
- Myrtaceae
  - *Eugenia*
  - *Leptospermum*
- Rosaceae
  - *Pygeum*
- Rubiaceae
  - *Hymenodictyon*
- Rutaceae
  - *Citrus* (?)
- Solanaceae
  - *Acnistus*
  - *Cestrum*
  - *Datura*
- Thymelaeaceae
  - *Daphne*
  - *Daphnopsis*
  - *Lasiosiphon*
  - *Schoenobiblus*
- Ulmaceae
  - *Gironniera*
- Umbelliferae
  - *Eryngium*
  - *Peucedanum*
  - *Steganotaenia*

VIII. RAPHIDES

(See also list on p. 1345)

Ampelidaceae
Dilleniaceae
Marcgraviaceae
Melianthaceae
Nyctaginaceae
Phytolaccaceae
Rubiaceae
Rutaceae
Saurauiaceae
Tetrameristicaceae
Urticaceae

IX. OIL OR MUCILAGE CELLS

(See also list on p. 1347)

Annonaceae
Aristolochiaceae
Burseraceae
Canellaceae
Dilleniaceae
Hernandiaceae
Lauraceae
Magnoliaceae
Monimiaceae
Myristicaceae
Piperaceae
Rutaceae
Saurauiaceae
Schisandraceae
Winteraceae

GEOGRAPHICAL DISTRIBUTION

It is generally recognized that the relationship between the geographical distribution of plants on the one hand and their taxonomy and phylogeny on the other, is of considerable interest. Whilst it is definitely beyond the scope of this book to deal with the complexities of geographical distribution in detail, it is anticipated that readers may find it useful to have ready access to tables and notes which give some idea of the approximate distribution of each family.

In the following lists the families have, for convenience, been arbitrarily classified in 4 main groups as follows. (1) Wide distribution. (2) Restricted distribution. (3) Very local distribution. (4) Wide but discontinuous or otherwise noteworthy distribution. As can be seen below, each of these 4 groups has been subdivided into a number of geographical regions which are more precisely defined. All of the information concerning geographical distribution has been collected from various well-known publications such as the text-books by Hutchinson (1113), Wettstein (2416), &c.

I. WIDE DISTRIBUTION

Cosmopolitan

Amaranthaceae
Aquifoliaceae
Callitrichaceae
Campanulaceae
Caprifoliaceae
Celastraceae
Ceratophyllaceae
Chenopodiaceae
Compositae
Convolvulaceae
Cruciferae
Droseraceae
Elatinaceae
Euphorbiaceae
Gentianaceae—Menyanthoideae
Haloragaceae
Labiatae
Leguminosae
Lythraceae
Malvaceae
Plantaginaceae
Polygonaceae
Rosaceae
Santalaceae
Scrophulariaceae
Solanaceae
Tiliaceae
Urticaceae
Valerianaceae
Verbenaceae

Tropical regions in general

Basellaceae
Begoniaceae
Bixaceae
Bombacaceae
Burseraceae
Capparidaceae
Cochlospermaceae
Combretaceae
Connaraceae
Dichapetalaceae
Erythroxylaceae
Guttiferae
Hernandiaceae
Hippocrateaceae
Icacinaceae
Lecythidaceae
Malpighiaceae
Melastomaceae
Myristicaceae
Myrsinaceae
Ochnaceae
Piperaceae
Podostemaceae (especially America)
Rhizophoraceae
Sapotaceae
Simarubaceae

Tropics of the new world

Bonnetiaceae
Brunelliaceae
Cactaceae
Caricaceae
Caryocaraceae
Diclidantheraceae
Goupiaceae
Julianiaceae
Krameriaceae
Lacistemaceae
Marcgraviaceae
Pellicieraceae
Quiinaceae
Trigoniaceae
Turneraceae

Tropics of the old world

Alangiaceae
Ancistrocladaceae
Dipterocarpaceae
Moringaceae
Opiliaceae

Tropical and sub-tropical

Acanthaceae
Ampelidaceae
Annonaceae
Apocynaceae
Asclepiadaceae
Balanophoraceae
Bignoniaceae
Crassulaceae (dry regions)
Datiscaceae
Dilleniaceae
Ebenaceae
Elaeocarpaceae
Ficoidaceae (deserts)
Gesneriaceae
Hydnoraceae
Lauraceae
Loganiaceae
Meliaceae
Menispermaceae
Monimiaceae
Myrtaceae (especially Australia)
Olacaceae
Passifloraceae
Phytolaccaceae
Punicaceae
Rafflesiaceae
Rutaceae
Sabiaceae
Saurauiaceae
Sterculiaceae
Styracaceae
Zygophyllaceae

Mainly tropical but some temperate

Anacardiaceae
Araliaceae
Balsaminaceae
Cucurbitaceae
Flacourtiaceae
Hypericaceae
Linaceae
Lobeliaceae
Moraceae
Oxalidaceae
Pedaliaceae
Rubiaceae
Sapindaceae

Temperate and tropical

Aristolochiaceae
Elaeagnaceae
Lentibulariaceae
Loranthaceae
Oleaceae
Polygalaceae
Rhamnaceae
Violaceae

Mainly temperate but some tropical

Boraginaceae
Juglandaceae
Orobanchaceae
Ranunculaceae
Thymelaeaceae
Umbelliferae
Vacciniaceae

Temperate and sub-tropical

Buxaceae
Gentianaceae—Gentianoideae
Hydrangeaceae
Onagraceae
Papaveraceae
Platanaceae

Temperate regions in general

Betulaceae
Coriariaceae
Cornaceae
Escalloniaceae
Geraniaceae
Myricaceae
Saxifragaceae

North temperate

Aceraceae
Adoxaceae
Berberidaceae
Cannabinaceae
Caryophyllaceae
Cistaceae
Corylaceae
Diapensiaceae
Empetraceae
Fumariaceae
Grossulariaceae
Hippuridaceae
Monotropaceae
Primulaceae
Resedaceae
Ulmaceae

North temperate and tropical

Nymphaeaceae
Theaceae

II. RESTRICTED DISTRIBUTION

America (*north temperate*)

Hydrophyllaceae
Leitneriaceae
Limnanthaceae
Sarraceniaceae

America (*temperate and tropical*)

Calyceraceae
Cyrillaceae
Loasaceae
Nyctaginaceae

Africa (*tropical*)

Melianthaceae (Also sub-tropical)
Octoknemataceae
Scytopetalaceae

Africa (*South*)

Achariaceae
Bruniaceae
Geissolomataceae
Grubbiaceae

Africa and neighbouring islands

Africa and Madagascar—Myrothamnaceae
S. Africa and Madagascar—Hydrostachyaceae
S. and E. Africa and St. Helena—Oliniaceae
S. and E. Africa and Mascarene Islands—Globulariaceae, Selaginaceae
Tropical Africa and Mascarene Islands—Salvadoraceae

India and the Far East

China and Malaya—Pentaphylacaceae
China and Upper Burma—Tetracentraceae
India and the Far East—Eupteleaceae
India and Malaya—Crypteroniaceae
Malaya—Gonystylaceae, Tetrameristaceae
Malaya and the Far East—Daphniphyllaceae

Asia (*Eastern*)

Actinidiaceae
Cercidiphyllaceae
Eucommiaceae
Sargentodoxaceae
Stachyuraceae
Trochodendraceae

Australasia

Akaniaceae
Cunoniaceae
Epacridaceae
Eupomatiaceae
Himantandraceae
Stackhousiaceae
Tremandraceae

III. DISTRIBUTION VERY LOCAL

America (North), SW. regions—Fouquieraceae
Andes—Columelliaceae, Malesherbiaceae, Myzodendraceae, Tropaeolaceae
Arizona and Texas—Koeberliniaceae
Australia (SW.)—Cephalotaceae
California—Crossosomataceae
California and Mexico—Lennoaceae
Chile—Gomortegaceae
Himalayas—Circaeasteraceae
Juan Fernandez—Lactoridaceae
Mascarene Islands—Chlaenaceae, Didiereaceae
Mediterranean region and Canary Islands—Cneoraceae
New Caledonia—Balanopsidaceae
New Zealand and Pacific Islands—Corynocarpaceae
Seychelle Islands—Medusagynaceae

IV. FAMILIES WITH WIDE BUT DISCONTINUOUS OR OTHERWISE NOTEWORTHY DISTRIBUTION

America (Tropical) and N. Hemisphere generally—Hippocastanaceae
America (North), W. Indies, Brazil, India, Malaya and the Far East—Magnoliaceae
America (North), Africa, Madagascar and the Far East—Hamamelidaceae
America (North) and the Far East—Calycanthaceae, Nyssaceae
America (NW.) and the Andes—Polemoniaceae
America (SW. U.S.), Mexico, Guatemala and Jamaica—Garryaceae
America (SE. U.S.), Malaya, China and Australia—Schisandraceae
America (SE. U.S., Tropical) and Madeira—Clethraceae
America, Asia, and Australia (Warm parts of)—Symplocaceae
America (Tropical) and W. Africa—Vochysiaceae
America (Tropical) and Tropical Africa—Humiriaceae
America (Tropical), E. Africa and Madagascar—Canellaceae
America (N. and S.), Malaya, and the Far East—Staphyleaceae
America (S.), Antarctica, Australia, and Tropical Asia—Goodeniaceae, Stylidiaceae
America (S.) and SE. Asia—Winteraceae
America (S.) and E. Asia—Lardizabalaceae
America (South Temperate), S. Africa, India, and Australia—Proteaceae
Australia and Africa—Byblidaceae, Pittosporaceae
Australia, New Caledonia, and Malaya—Casuarinaceae
Australia and Japan—Myoporaceae
Australia, Tasmania, and Chile—Eucryphiaceae
Madagascar and Malaya—Nepenthaceae
Maritime Coasts, especially Mediterranean—Plumbaginaceae
Maritime Coasts, E. Africa to Australia—Sonneratiaceae
Maritime Regions in Tropical and Sub-tropical America—Batidaceae
Maritime and other saline regions—Frankeniaceae
Mediterranean and Central Asia—Tamaricaceae
Mediterranean and the Far East—Thelygonaceae
Old World except Australia—Dipsacaceae
Temperate and Tropical Regions excluding S. Africa—Fagaceae
Temperate (South) and Tropical Regions—Chloranthaceae
Widely Distributed but excluding Australia and Malaya—Salicaceae
Widely Distributed, chiefly in the New World—Portulacaceae
Widely Distributed, chiefly in S. Africa and China—Ericaceae

HABIT

In the following tables the woody habit is taken to include trees, shrubs, lianes, and ericoid shrubs.

I. WHOLLY WOODY

Aceraceae
Actinidiaceae
Akaniaceae
Alangiaceae
Ampelidaceae
Anacardiaceae
Ancistrocladaceae
Annonaceae
Aquifoliaceae
Araliaceae
Balanopsidaceae
Batidaceae
Betulaceae
Bixaceae
Bombacaceae
Bonnetiaceae
Brunelliaceae
Bruniaceae
Burseraceae
Buxaceae
Calycanthaceae
Canellaceae
Caricaceae
Caryocaraceae
Casuarinaceae
Celastraceae
Cercidiphyllaceae
Chlaenaceae
Clethraceae
Cneoraceae
Cochlospermaceae
Columelliaceae
Combretaceae
Connaraceae
Coriariaceae
Corylaceae
Corynocarpaceae
Crossosomataceae
Crypteroniaceae
Cunoniaceae
Cyrillaceae
Daphniphyllaceae
Datiscaceae
Diapensiaceae
Dichapetalaceae
Diclidantheraceae
Dipterocarpaceae
Ebenaceae
Elaeagnaceae
Elaeocarpaceae
Empetraceae
Epacridaceae
Ericaceae
Erythroxylaceae
Escalloniaceae
Eucommiaceae
Eucryphiaceae
Eupomatiaceae
Eupteleaceae
Fagaceae
Flacourtiaceae
Fouquieraceae
Garryaceae
Geissolomataceae
Gomortegaceae
Gonystylaceae
Goupiaceae
Grossulariaceae
Grubbiaceae
Guttiferae
Hamamelidaceae
Hernandiaceae
Himantandraceae
Hippocastanaceae
Hippocrateaceae
Humiriaceae
Hydrangeaceae
Icacinaceae
Juglandaceae
Julianiaceae
Koeberliniaceae
Krameriaceae
Lacistemaceae
Lactoridaceae
Lardizabalaceae
Lauraceae
Lecythidaceae
Leitneriaceae
Loranthaceae
Magnoliaceae
Malpighiaceae
Marcgraviaceae
Medusagynaceae
Meliaceae
Melianthaceae
Menispermaceae
Monimiaceae
Moringaceae
Myoporaceae
Myricaceae
Myristicaceae
Myrothamnaceae
Myrtaceae
Myzodendraceae
Nyssaceae
Octoknemaceae
Olacaceae
Oleaceae
Oliniaceae
Opiliaceae
Pellicieraceae
Penaeaceae
Pentaphylacaceae
Pittosporaceae
Platanaceae
Punicaceae
Quiinaceae
Rhamnaceae
Rhizophoraceae
Rosaceae—Chrysobalanoideae
Sabiaceae
Salicaceae
Salvadoraceae
Sapindaceae
Sapotaceae
Sargentodoxaceae
Saurauiaceae
Schisandraceae
Scytopetalaceae
Simarubaceae
Sonneratiaceae
Stachyuraceae
Staphyleaceae
Styracaceae
Symplocaceae
Tamaricaceae
Tetracentraceae
Tetrameristicaceae
Theaceae
Tremandraceae
Trigoniaceae
Trochodendraceae
Ulmaceae
Vacciniaceae
Vochysiaceae
Winteraceae

II. WOODY HABIT DOMINANT

Apocynaceae
Aristolochiaceae
Bignoniaceae
Caprifoliaceae
Cistaceae
Cornaceae
Dilleniaceae
Linaceae
Loganiaceae
Moraceae
Myrsinaceae
Ochnaceae
Proteaceae
Rutaceae
Santalaceae
Sterculiaceae
Thymelaeaceae
Tiliaceae
Zygophyllaceae

III. WOODY PLANTS AND HERBS IN VARIOUS PROPORTIONS

Achariaceae
Asclepiadaceae
Berberidaceae
Capparidaceae
Chloranthaceae
Euphorbiaceae
Globulariaceae
Hypericaceae
Leguminosae
Lythraceae
Malesherbiaceae
Malvaceae
Melastomaceae
Nyctaginaceae
Passifloraceae
Phytolaccaceae
Polygalaceae
Rosaceae
Rubiaceae
Selaginaceae
Solanaceae
Urticaceae
Verbenaceae
Violaceae

IV. HERBACEOUS HABIT DOMINANT

Acanthaceae
Amaranthaceae
Begoniaceae
Boraginaceae
Byblidaceae
Cactaceae
Campanulaceae
Chenopodiaceae
Compositae
Convolvulaceae
Cruciferae
Cucurbitaceae
Droseraceae
Elatinaceae
Ficoidaceae
Frankeniaceae
Gentianaceae—Gentianoideae
Geraniaceae
Gesneriaceae
Goodeniaceae
Hydrophyllaceae
Labiatae
Loasaceae
Lobeliaceae
Onagraceae
Oxalidaceae
Papaveraceae
Piperaceae
Plantaginaceae
Plumbaginaceae
Polemoniaceae
Polygonaceae
Portulacaceae
Primulaceae
Ranunculaceae
Scrophulariaceae
Stylidiaceae
Turneraceae
Umbelliferae

V. WHOLLY HERBACEOUS

Adoxaceae
Balanophoraceae
Balsaminaceae
Basellaceae
Callitrichaceae
Calyceraceae
Cannabinaceae
Caryophyllaceae
Cephalotaceae
Ceratophyllaceae
Circaeasteraceae
Crassulaceae
Didiereaceae
Dipsacaceae
Fumariaceae
Gentianaceae—Menyanthoideae
Haloragaceae
Hippuridaceae
Hydnoraceae
Hydrostachyaceae
Lennoaceae
Lentibulariaceae
Limnanthaceae
Monotropaceae
Nepenthaceae
Nymphaeaceae
Orobanchaceae
Pedaliaceae
Podostemaceae
Rafflesiaceae
Resedaceae
Sarraceniaceae
Saururaceae
Saxifragaceae
Stackhousiaceae
Thelygonaceae
Tropaeolaceae
Valerianaceae

APPENDIX I

DISTRIBUTION OF CELL DIMENSIONS, ETC., IN DICOTYLEDONOUS WOODS

TABLE 1. *Mean Vessel Diameter*

Frequency class *μ*	*Species*	
	Number	*Per cent.*
0–39	149	10·0
40–79	609	40·7
80–119	311	20·7
120–159	231	15·4
160–199	119	7·9
200–239	57	3·8
240–279	13	0·9
280–319	8	0·5
320–359	2	0·1
360–399	1	0·0
	1,500	100·0

Arithmetic mean 93·99μ. Median 79·5μ.

TABLE 2. *Mean Vessel Member Length*

Frequency class *μ*	*Species*	
	Number	*Per cent.*
0–199	30	5·0
200–399	159	26·6
400–599	163	27·2
600–799	95	15·8
800–999	51	8·5
1,000–1,199	35	5·8
1,200–1,399	26	4·3
1,400–1,599	13	2·2
1,600–1,799	15	2·5
1,800–1,999	4	0·7
2,000–2,199	5	0·8
2,200–2,399	2	0·3
2,400–2,599	2	0·3
	600	100·0

Arithmetic mean 649μ. Median 533μ.

TABLE 3. *Number of Vessels and Vessel Groups per Millimetre*

Frequency class	*Species*	
	Number	*Per cent.*
0 & 1	65	3·8
2 & 3	194	11·4
4 & 5	184	10·8
6 & 7	153	9·0
8 & 9	142	8·4
10–19	361	21·20
20–29	180	10·60
30–39	110	6·50
40–49	70	4·13
50–59	42	2·47
60–69	48	2·82
70–79	19	1·12
80–89	20	1·17
90–99	16	0·94
100–149	55	3·24
150–199	15	0·88
200–249	12	0·70
250–299	8	0·47
300–349	5	0·30
350–399	0	0·0
400–449	1	0·06
	1,700	100·0

Arithmetic mean 31·25.

TABLE 4. *Mean Fibre Length*

Frequency class μ	*Species*	
	Number	*Per cent.*
0–299	3	0·5
300–599	39	7·3
600–899	87	16·3
900–1,199	125	23·4
1,200–1,499	111	20·8
1,500–1,799	80	15·0
1,800–2,099	31	5·8
2,100–2,399	27	5·1
2,400–2,699	14	2·6
2,700–2,999	12	2·2
3,000–3,299	3	0·6
3,300–3,599	2	0·4
	534	100·0

Arithmetic mean 1,317·5μ. Median 1,132·5μ.

TABLE 5. *Maximum Width of Rays*

Frequency class μ	*Species* *Number*	*Species* *Per cent.*
0–19	82	12·6
20–39	165	25·5
40–59	163	25·1
60–79	87	13·4
80–99	47	7·2
100–119	30	4·6
120–139	14	2·16
140–159	11	1·7
160–179	7	1·07
180–199	6	0·9
200–219	4	0·61
220–239	3	0·46
240–259	3	0·46
260–279	4	0·60
280–299	1	0·15
300–399	10	1·53
400–499	3	0·45
500–599	2	0·3
600–699	4	0·6
700–799	3	0·46
800–899	1	0·15
	650	100·0

Arithmetic mean 63·5 μ. Median 49·5 μ.

TABLE 6. *Number of Rays per Millimetre*

Frequency class	*Species* *Number*	*Species* *Per cent.*
0–1·9	27	1·5
2–3·9	125	7·0
4–5·9	189	10·5
6–7·9	234	13·0
8–9·9	288	16·0
10–11·9	241	13·4
12–13·9	226	12·5
14–15·9	178	9·9
16–17·9	109	6·1
18–19·9	82	4·6
20–21·9	58	3·2
22–23·9	25	1·4
24–25·9	9	0·5
26–27·9	8	0·4
28–29·9	0	0·0
30–31·9	1	0·0
	1,800	100·0

Arithmetic mean 10·15. Median 10·2.

BIBLIOGRAPHY

REFERENCES to literature published before 1908 have nearly all been omitted from the following list, as they may readily be obtained from Solereder's book on the *Systematic Anatomy of the Dicotyledons* (No. 2158 in the list below). All references in the text to Solereder's views and statements refer to this work, unless otherwise stated. The contractions used for the titles of the journals are those adopted in the *World List of Scientific Periodicals*, Clarendon Press, Oxford, 2nd edition, 1934.

1. ABESSADZE, A. Über den Bau des kaukasichen Rhododendron. Bull. Jard. bot. princip. U.R.S.S. **26,** 209–22; 1927. *See* Bot. Zbl., N.S. **13,** 389; 1928.
2. ADAMSON, R. S. On the comparative anatomy of the leaves of certain species of *Veronica.* J. linn. Soc. (Bot.), **40,** 247–74; 1912.
3. —— Anomalous secondary thickening in Compositae. Ann. Bot. Lond. **48,** 505–14; 1934.
4. —— Note on the stem structure of *Boscia Rehmanniana* Post. Trans. roy. Soc. S. Afr. **23,** 297–301; 1936.

· Anomalous secondary thickening in *Osteospermum.* Trans. roy. Soc. S. Afr. **24,** 303–12; 1937.

6. ADDICOT, F. T. The anatomy of leaf abscission and experimental defoliation in guayule. Amer. J. Bot. **32,** 250–6; 1945.
7. ADDOMS, R. M., and MOUNCE, F. C. Notes on the nutrient requirements and the histology of the cranberry (*Vaccinium macrocarpum* Ait.) with special reference to Mycorrhiza. Plant Physiol. **6,** 653–68; 1931.
8. ADKINSON, J. Some features of the anatomy of the Vitaceae. Ann. Bot. Lond. **27,** 133–9; 1913.
9. AIRY-SHAW, H. K. The Pentaphragmataceae of the Oxford University expedition to Sarawak, 1932. Kew Bull. **3,** 233–6; 1941.
10. AKERMAN, G. *Beiträge zur Pharmakognosie der Salicaceen. Anatomie und Entwicklungsgeschichte der Rinde.* Thesis, Zagreb, pp. 64; 1937.
11. ALDRICH-BLAKE, R. N. *On the fixation of atmospheric nitrogen by bacteria living symbiotically in root nodules of Casuarina equisetifolia.* Oxford Forestry Memoirs, **14,** pp. 20; 1932.
12. ALEXANDROV, W. G. Über ein neues Beispiel einer besonderen Art des Wassergewebes in den Blättern. Ber. dtsch. bot. Ges. **43,** 418–26; 1925.
13. —— Sur la disposition des cellules cristallifères et dans les cellules renfermant des substances protéiques dans les racines et les tiges de la vigne. Zh. russk. bot. Absch. **10,** 287–92; 1925. *See* Just's Jber., Pt. 2, 475; 1926.
14. —— Über die Entwicklungsfolge der Gefässverdickungen. Ber. dtsch. bot. Ges. **44,** 85–94; 1926.
15. —— Beiträge zur Kenntnis des Gefässbündels der dikotylen Krautpflanze. Ber. dtsch. bot. Ges. **47,** 451–60; 1929.
16. ALEXANDROV, W. G., and ABESSADZE, K. J. Beiträge zur Feststellung der Gesetzmässigkeiten in der Gefässbildung des Leitbündels der Dikotylen. Beitr. Biol. Pfl. **22,** 225–34; 1934.
17. ALEXANDROV, W. G., and ALEXANDROVA, O. G. Über konzentrische Gefässbündel im Stengel von *Ricinus communis.* Bot. Arch. **14,** 455–61; 1926. *See* Just's Jber., Pt. 2, 476; 1926.
18. —— Über die Struktur verschiedener Abschnitte ein und desselben Bündels und den Bau von Bündeln verschiedener Internodien des Sonnenblumenstengels. Planta, **8,** 465–86; 1929.

Allen, C. K. Studies in the Lauraceae:

19. V. Some Eastern Asiatic species of *Beilschmiedia* and related genera. J. Arnold Arbor. **23,** 444–63; 1942.

20. VI. Preliminary survey of the Mexican and Central American species. J. Arnold Arbor. **26,** 365–434; 1945.

21. Allen, E. K., and Allen, O. N. Attempts to demonstrate symbiotic nitrogen-fixing bacteria within the tissues of *Cassia Tora*. Amer. J. Bot. **20,** 79–84; 1933.

22. Allsopp, A., and Misra, P. The constitution of the cambium, the new wood and the mature sapwood of the common ash, the common elm and the Scotch pine. Bio-Chem. J. **34,** 1078–84; 1940.

23. Almeida, G. D. de. Note on a Cordia wood from Eastern Brazil. Trop. Woods, **89,** 48–52; 1947.

24. Alquati, P. Studi anatomici e morfologici sull' ulevo. S-A. Atti igustica di scienze naturali. **17,** pp. 74; 1906. *See* Just's Jber., Pt. 1, 429; 1908.

25. Amaldi, P. Osservazione sull' anatomica del ligno secondario dell' *Olea chrysophylla*. Nuovo G. bot. ital. **36,** 282–99; 1929.

26. Anderson, E. A survey of modern opinion. Bull. Torrey bot. Cl. **67,** 363–9; 1940.

27. Anonymous. How to identify Jarrah and Karri by microscopical examination. Aust. For. J. **9,** 16–18; 1926.

28. —— Biologie, anatomie et physiologie de l'arachide. Rev. Bot. appl. **14,** 565–614; 1934.

29. Arber, A. *Water plants.* Cambridge, pp. 436; 1920.

30. —— The tree habit in angiosperms; its origin and meaning. New Phytol. **27,** 69–84; 1928.

31. —— Root and shoot in the angiosperms. A study of morphological categories. New Phytol. **29,** 5. 297–315; 1930.

32. —— On the morphology of the pitcher leaves in *Heliamphora, Sarracenia, Darlingtonia, Cephalotus* and *Nepenthes*. Ann. Bot. Lond. **5,** 563–78; 1941.

33. —— The interpretation of leaf and root in the angiosperms. Biol. Rev. Camb. phil. soc. **16,** pp. 24; 1941.

34. Arens, F. *Loranthus sphaerocarpus* auf *Dracaena* sp. Ein Fall des Parasitierens einer Loranthacee auf eine Monokotyle. Zugleich ein Beitrag zur näheren Kenntnis des Loranthaceen-Haustoriums. Zbl. Bakt. **2,** 32, pp. 24; 1911. *See* Just's Jber., Pt. 2, 1064; 1911.

35. Armand, M. L. Recherches morphologiques sur le *Lobelia Dortmanna* I. Rev. gen. Bot. **24,** 465–78; 1912. *See* Just's Jber., Pt. 2, 796; 1912.

36. Arnaudow, N. Über die Anatomie von *Lathrea rhodopea* Dingler. Jb. Univ. Sofia, **22,** 2. Nat. Abt. 149–58; 1926. *See* Just's Jber., Pt. 1, 935; 1927.

37. Artschwager, E. F. Anatomy of the potato plant, with special reference to the ontogeny of the vascular system. J. Agric. Res. **14,** 221–52; 1918.

38. —— On the anatomy of *Chenopodium album* L. Amer. J. Bot. **7,** 252–60; 1920.

39. —— On the anatomy of the sweet potato root with notes on internal breakdown. J. Agric. Res. **27,** 157–66; 1924.

40. —— Anatomy of the vegetative organs of the sugar beet. J. Agric. Res. **33,** 143–76; 1926.

41. —— A study of the structure of sugar beet in relation to sugar content and type. J. Agric. Res. **40,** 867–915; 1930.

42. —— Observations on the effect of environmental conditions on the structure of the lateral roots of sugar beet. J. Agric. Res. **55,** 81–6; 1937.

43. —— *Contribution to the morphology and anatomy of guayule* (*Parthenium argentatum*). U.S. Dept. Agric. Washington D.C. Tech. Bull., No. 842, pp. 33; 1943.

44. Artschwager, E. F., and Starrett, R. C. Histological and cytological changes in sugar beet seedlings affected with curly top. J. Agric. Res. **53,** 637–57; 1936.

45. Arzt, Th. Die Kutikula einiger afrikanischer Mangrove-Pflanzen. Ber. dtsch. bot. Ges. **54,** 247–60; 1936.

46. Ashplant, H. Investigations into *Hevea* anatomy. Bull. Rubb. Gr. Ass. **10,** 484–90; 796–800; 1928.

47. Astrov, A. V. Materials for the characteristic of the stem structure in the varieties of guayule. Bull. appld. Bot. Select., Ser. 1, **1,** 189–209; 1932. English summary.

48. Aubertot, M. Sur l'anatomie comparée des rameaux polymorphes chez quelques arbustes épineux de la famille Rosacées. Bull. Soc. bot. Fr. **57,** 615–19; 1910.

49. Aubréville, A. Notes sur le Sipo de Sassandra (*Entandrophragma* sp.). Bull. mens. de l'Agence économique de l'Afrique occidentale française, **8,** 84. 273–5; 1927.

50. —— Notes sur le Dibetou (*Lovoa Klaineana*). Bull. mens. de l'Agence économique de l'Afrique occidentale française, **9,** 87. 91–3; 1928.

51. —— Essai d'identification des Méliacées de la Côte d'Ivoire. C. R. Ass. Col.-Sci. Paris, **6,** 57/58, 1–15; 1930.

52. —— Les Sterculiacées de la Côte d'Ivoire. C. R. Ass. Col.-Sci. Paris, **6,** 61, 164–8; 1930.

53. —— Les Entandrophragma de la Côte d'Ivoire. C. R. Ass. Col.-Sci. Paris, **7,** 72. 121–9; and **7,** 73. 145–55; 1931.

54. Aubréville, A., *et al. Le Bossé, Guarea cedrata* (*A. Chev.*) *Pellegr.* Assoc. Col.-Sc. & Comité Nat. des Bois Coloniaux, pp. 30; 1928.

55. Aubréville, A., Besson, A., Berengier, E., Collardet, J., Normand, D., and Petitpas, J. L'Iroko. Bois et For. des Trop. **1,** 34–52; 1947.

56. Audas, J. W., and Morris, P. F. A new species of *Persoonia* from Western Australia. J. roy. Soc. W. Aust. **15,** 81–2; 1929 (1928).

57. Avery, G. S., Jun. Structure and germination of tobacco seed and the developmental anatomy of the seedling plant. Amer. J. Bot. **20,** 309–27; 1933 (*a*).

58. —— Structure and development of the tobacco leaf. Amer. J. Bot. **20,** 565–92; 1933 (*b*).

59. —— Structural responses to the practice of topping tobacco plants: a study of cell size, cell number, leaf size and veinage of leaves at different levels on the stalk. Bot. Gaz. **96,** 314–29; 1934.

60. Baccarini, P. Notizie sulla struttura anatomica della *Modecca abyssinica* Hochst. Bull. Soc. bot. Ital. 40–9; 1909. *See* Just's Jber., Pt. 1, 984; 1909.

61. Bachtadze, I. Untersuchung der Abchasischen Tabaksorten. Bull. Inst. exper. Agric. Georgia, **2,** 3–26; 1929. *See* Bot. Zbl., N.S. **17,** 374; 1930.

62. Baehni, C. Revision du genre *Mollia.* Candollea, **5,** 402–26; 1934.

—— Mémoires sur les Sapotacées:

63. I. Système de classification. Candollea, **7,** 394–508; 1938.

64. II. Le Genre *Pouteria.* Candollea, **9,** 147–475; 1942.

65. Bailey, I. W. Reversionary characters of traumatic oak woods. Bot. Gaz. **50,** 374–80; 1910.

66. —— Notes on the wood structure of the Betulaceae and Fagaceae. For. Quart. **8,** 178–85; 1910.

67. —— The relation of the leaf-trace to the formation of the compound rays in the lower dicotyledons. Ann. Bot. Lond. **25,** 225–41; 1911.

68. —— The evolutionary history of the foliar ray in the wood of dicotyledons. Ann. Bot. Lond. **26,** 647–61; 1912.

69. —— Investigations on the phylogeny of the angiosperms. Bot. Gaz. **58,** 36–60; 1914.

70. —— The anatomy of certain plants from the Belgian Congo, with special reference to myrmecophytism. Bull. Amer. Mus. nat. Hist. **45,** 585–621; 1922.

71. —— The problem of identifying the wood of cretaceous and later dicotyledons: *Paraphyllanthoxylon arizonense.* Ann. Bot. Lond. **38,** 439–51; 1924.

72. —— Notes on neotropical ant plants: III. *Cordia nodosa.* Bot. Gaz. **77,** 32–49; 1924.

73. BAILEY, I. W. Preliminary notes on cribriform and vestured pits. Trop. Woods, **31**, 46–8; 1932.

74. —— The problem of differentiating and classifying tracheids, fibre-tracheids, and libriform wood fibres. Trop. Woods, **45**, 18–23; 1936.

75. —— The development of vessels in angiosperms and its significance in morphological research. Amer. J. Bot. **31**, 421–8; 1944. *See* Biol. Abstr. **18**, No. 201981; 1944.

—— The cambium and its derivative tissues:

76. II. Size variations of cambium initials in gymnosperms and angiosperms. Amer. J. Bot. **7**, 355–67; 1920.

77. IV. The increase in girth of the cambium. Amer. J. Bot. **10**, 499–509; 1923.

78. VIII. Structure, distribution and diagnostic significance of vestured pits in dicotyledons. J. Arnold Arbor. **14**, 259–73; 1933.

—— (and FAULL, A. F.)

79. IX. Structural variability in the redwood, *Sequoia sempervirens*, and its significance in the identification of fossil woods. J. Arnold Arbor. **15**, 233–54; 1934.

80. BAILEY, I. W., and BERKLEY, E. E. The significance of X-rays in studying the orientation of cellulose in the secondary wall of tracheids. Amer. J. Bot. **29**, 231–41; 1942.

BAILEY, I. W., and HOWARD, R. A. The comparative morphology of the Icacinaceae:

81. I. Anatomy of the node and internode. J. Arnold Arbor. **22**, 125–32; 1941.

82. II. Vessels. J. Arnold Arbor. **22**, 171–87; 1941.

83. III. Imperforate tracheary elements and xylem parenchyma. J. Arnold Arbor. **22**, 432–42; 1941.

84. IV. Rays of the secondary xylem. J. Arnold Arbor. **22**, 556–68; 1941.

85. BAILEY, I. W., and KERR, T. The structural variability of the secondary wall as revealed by 'lignin' residues. J. Arnold Arbor. **18**, 261–72; 1937.

BAILEY, I. W., and NAST, C. G. The comparative morphology of the Winteraceae:

86. I. Pollen and stamens. J. Arnold Arbor. **24**, 340–5; 1943.

87. II. Carpels. J. Arnold Arbor. **24**, 472–81; 1943.

88. III. Wood. J. Arnold Arbor. **25**, 97–103; 1944.

89. IV. Anatomy of the node and vascularization of the leaf. J. Arnold Arbor. **25**, 215–20; 1944.

90. V. Foliar epidermis and sclerenchyma. J. Arnold Arbor. **25**, 342–8; 1944.

VI. *See under* NAST, C. G.

91. VII. Summary and conclusions. J. Arnold Arbor. **26**, 37–47; 1945.

—— Morphology and relationships of *Trochodendron* and *Tetracentron*:

92. I. Stem, root, and leaf. J. Arnold Arbor. **26**, 143–54; 1945.

II. *See under* NAST, C. G., AND BAILEY, I. W.

93. —— Morphology of *Euptelea* and comparison with *Trochodendron*. J. Arnold Arbor. **27**, 186–91; 1946.

94. BAILEY, I. W., NAST, C. G., and SMITH, A. C. The family Himantandraceae. J. Arnold Arbor. **24**, 190–206; 1943.

95. BAILEY, I. W., and PRICHARD, H. P. The significance of certain variations in the anatomical structure of wood. For. Quart. **14**, 662–70; 1916.

96. BAILEY, I. W., and SHEPARD, H. W. Sanio's laws for variation in size of coniferous tracheids. Bot. Gaz. **60**, 66–71; 1915.

97. BAILEY, I. W., and SINNOTT, E. W. The origin and dispersal of herbaceous angiosperms. Ann. Bot. Lond. **28**, 547–600; 1914.

98. BAILEY, I. W., and SMITH, A. C. Degeneriaceae, a new family of flowering plants from Fiji. J. Arnold Arbor. **23**, 356–65; 1942.

99. BAILEY, I. W., and THOMPSON, W. P. Additional notes upon the angiosperms, *Tetracentron*, *Trochodendron*, and *Drimys*, in which vessels are absent from the wood. Ann. Bot. Lond. **32,** 28: 503–12; 1918.

100. BAILEY, I. W., and TUPPER, W. W. Size variations in tracheary cells: I. a comparison between the secondary xylems of vascular cryptogams, gymnosperms and angiosperms. Proc. Amer. Acad. Arts Sci. **54,** 149–204; 1918.

101. BAIN, H. F. Origin of adventitious shoots in decapitated Cranberry seedlings. Bot. Gaz. **101,** 4. 872–80; 1940.

102. BAIRD, M. M. Anatomy of *Platanus occidentalis*. Kans. Univ. Sci. Bull. **9,** 281–90; 1915.

103. BAKER, R. T. The Australian grey mangrove. J. roy. Soc. N.S.W. **49,** 257–81: 1915.

104. —— On the occurrence of crystals in some Australian timbers. J. roy. Soc. N.S.W. **51,** 435–44; 1917.

105. —— On the technology and anatomy of some silky oak timbers. J. roy. Soc. N.S.W. **52,** 362–76; 1918.

106. —— *The hardwoods of Australia and their economics.* Tech. Educ. Ser., No. 3, Sydney, pp. 522; 1919.

BAKER, R. T., and SMITH, H. G. The Australian melaleucas and their essential oils:

107. I. J. roy. Soc. N.S.W. **40,** 60–9; 1907.

108. II. J. roy. Soc. N.S.W. **41,** 196–210; 1907.

109. III. J. roy. Soc. N.S.W. **44,** 592–615; 1910.

110. IV. J. roy. Soc. N.S.W. **45,** 365–78; 1912.

111. V. J. roy. Soc. N.S.W. **47,** 193–214; 1913.

112. —— On an undescribed *Darwinia* and its essential oil. J. roy. Soc. N.S.W. **50,** 181–6; 1916.

113. —— *Wood fibres of some Australian timbers.* Sydney, pp. 159; 1924.

114. BALLARD, C. W. Microscopy of cinchona barks and adulterants. J. Amer. pharm. Ass. **4,** 78–106; 1915.

115. —— Histology of *Cocillana* and substitute barks. J. Amer. pharm. Ass. **11,** 781–7; 1922.

116. —— Structural variations in *Erythroxylon* leaves. J. Amer. pharm. Ass. **15,** 343–59, 433–54, 530–49; 1926. *See* Just's Jber., Pt. 2, 425; 1926.

117. —— Taxonomy and pharmacognosy of the genus *Apocynum*. Proc. Internt. Cong. plant Sci. **2,** 1406–12; (1926), 1929.

118. BALWANT SINGH. The origin and distribution of inter- and intraxylary phloem in *Leptadenia*. Proc. Indian Acad. Sci. **18,** Sect. B, 14–19; 1943.

119. —— A contribution to the anatomy of *Salvadora persica* L. with special reference to the origin of the included phloem. J. Indian bot. Soc. **23,** 71–8; 1944.

120. BAMBACIONI-MEZZETTI, V. Contributo all' anatomia comparata delle querce Italianee. Ann. Bot. Roma, **20,** 274–314; 1934.

121. BANCROFT, H. The arborescent habit in the angiosperms. A review. New Phytol. **29,** 153–69 and 227–75; 1930.

122. —— On the identification of isolated timber specimens, with special reference to fossil woods. Ann. Bot. Lond. **46,** 353–65; 1932.

123. —— Some fossil dicotyledonous woods from the Miocene beds of East Africa. Ann. Bot. Lond. **46,** 745–67; 1932.

124. —— On certain fossil plants from East Africa. Ann. Bot. Lond. **47,** 915–20; 1933.

125. —— A contribution to the geographical history of the Dipterocarpaceae. Geol. Fören. Stockh. Förh. **55,** 59–100; 1933.

126. —— New material of *Monotes Kerstingii* from the Gold Coast. Kew Bull. No. 6, 233–7; 1934.

127. —— The taxonomic history and geographical distribution of the Monotoideae. Amer. J. Bot. **22,** 505–19; 1935.

128. Bancroft, H. The wood anatomy of representative members of the Monotoideae. Amer. J. Bot. **22,** 717–39; 1935.

129. Bandulska, H. On the cuticles of some recent and fossil Fagaceae. J. linn. Soc. Bot. **46,** 241–69 and 427–41; 1922–4.

130. —— On the cuticles of some fossil and recent Lauraceae. J. linn. Soc. Bot. **47,** 383–425; 1925.

131. —— Secretory cells in a fossil leaf. Ann. Bot. Lond. **43,** 203–4; 1929.

132. —— On the cuticles of some recent and fossil Myrtaceae. J. linn. Soc. Bot. **48,** 657–71; 1930.

133. Bannan, M. W. Wood structure of *Ryania*. Amer. J. Bot. **30,** 351–5; 1943.

Baranov, P. Matériaux à l'anatomie des plantes de montagne:

134. II. Essai de la caractéristique comparative anatomique des xérophytes et mésophytes des montagnes. Bull. Univ. Asie cent. **8,** 1–27; 1925.

135. III. Caractéristique anatomique de la végétation des éboulis pierreux. Bull. Univ. Asie cent. **10,** 1–15; 1925.

136. Barghoorn, E. S., Jun. Origin and development of the uniseriate ray in the Coniferae. Bull. Torrey Bot. Cl. **67,** 303–28; 1940.

—— The ontogenetic development and phylogenetic specialization of rays in the xylem of dicotyledons:

137. I. The primitive ray structure. Amer. J. Bot. **27,** 918–28; 1940.

138. II. Modification of the multiseriate and uniseriate rays. Amer. J. Bot. **28,** 273–82; 1941.

139. III. The elimination of rays. Bull. Torrey Bot. Cl. **68,** 317–25; 1941.

140. Barkley, F. A. A monographic study of *Rhus* and its immediate allies in North and Central America, including the West Indies. Ann. Missouri bot. Gard. **24,** 266–498; 1937.

141. Barkley, G. Differentiation of vascular bundles of *Trichosanthes anguina*. Bot. Gaz. **83,** 173–84; 1927.

142. Barratt, K. The origin of the endodermis in the stem of *Hippuris*. Ann. Bot. Lond. **30,** 91–9; 1916.

143. —— A note on an abnormality in the stem of *Helianthus annuus*. Ann. Bot. Lond. **30,** 481–4; 1916.

144. Barss, A. F. Effect of moisture supply on the development of *Pyrus communis*. Bot. Gaz. **90,** 151–75; 1930.

145. Bartlett, H. H. History of the generic concept in botany. Bull. Torrey bot. Cl. **67,** 349–62; 1940.

146. Bartorelli, I. Di un nuova carattere farmacognostico della Belladonna (*Atropa Belladona* L.). Ann. Bot. Roma, **15,** 273–5; 1922.

147. Bastos, A. de M. Modernos processos de identificação das madeiras. Bol. Esc. Chem. Indust. Annexa Mus. Commercial (Brazil), No. 1; 1930.

148. —— Os caracteres anatómicos das madeiras. Bol. Minist. Agric. B. Aires, No. 24, pp. 30; 1935.

149. —— El estudio de la estructura de las madeiras. Maderil, **8,** 96. 5–16; 1936.

150. —— Curso prático de anatomia de madeiras. J. Commercio (Rio de Janeiro), **8,** 3; 1937.

151. Batham, E. J. Vascular anatomy of New Zealand species of *Gunnera*. Trans. roy. Soc. N. Zealand, **73,** 209–16; 1943.

152. Batrany, L. Beiträge zur Histologie der Vegetations-organe von *Sibiraea croatica* Deg. Bot. Közl. **23,** 44–54; 1926. *See* Just's Jber., Pt. 2, 425; 1926 and Bot. Zbl., n.s. **12,** 71; 1928.

153. Baumgärtel, O. Die Anatomie der Gattung *Arthrocnemum* Moqu. S.B. Acad. Wiss. Wien. Math.-Naturw. Kl. **126,** pp. 14; 1917. *See* Bot. Zbl. **137,** 243; 1918.

154. Bausch, J. A revision of the Eucryphiaceae. Kew Bull. No. 8, 317–49; 1938.

155. Bausor, S. C., Reinhart, W. L., and Tice, G. A. Histological changes in tomato stems incident to treatment with β-naphthoxyacetic acid. Amer. J. Bot. **27,** 769–79; 1940.

Beakbane, A. B., *et al.* Anatomical studies of stems and roots of hardy fruit trees:

(and Thompson, E. C.)

156. II. The anatomical structure of the roots of some vigorous and some dwarfing apple rootstocks and the correlation of structure with vigour. J. Pomol. **17,** 141–9; 1939.

157. III. The anatomical structure of some clonal and seedling apple rootstocks stem- and root-grafted with a scion variety. J. Pomol. **18,** 344–67; 1941.

158. Beakbane, A. B., and Renwick, M. E. A preliminary report on the internal structure of the wood of No. IX rootstock in relation to scion-rooting of apples. Rep. E. Malling Res. Stat. 100–6; 1935 (1936).

159. Beakbane, A. B., and Thompson, E. C. Recognition of 'rubbery' condition in Lord Lambourne and other apple varieties. Rep. E. Malling Res. Stat. 108–9; 1944 (1945).

160. —— Accelerating rootstock research. Rep. E. Malling Res. Stat. 106–8; 1944 (1945).

161. —— Abnormal lignification in the wood of some apple trees. Nature, Lond. **156,** 145; 1945 and Rep. E. Malling Res. Stat. 36–7; 1944 (1945).

162. Beauquesne, L. Recherches sur quelques Ménispermacées médicinales des genres *Tinospora* et *Cocculus*. Trav. Lab. Mat. méd. Paris, **28,** pp. 181; 1937.

163. Beauvisage, L. *Contribution à l'étude anatomique de la famille des Ternstroemiacées* Tours, pp. 470; 1920.

164. Becking, J. H., Berger, L. G. den, and Meindersma, H. W. Vloed- of mangrovebosschen in Ned. Indië. Tectona, **15,** 561–611; 1922.

165. Beck-Mannagetta, G. *Orobanchaceae* in Engler's *Das Pflanzenreich*, iv. 261; 1930.

166. Bedelian, J. Recherches anatomiques sur les Cactées au point de vue d' adaption au climat sec. Nuovo G. bot. Ital., n.s. **18,** 399–458; 1911.

167. Beekman, H. 78 Preanger houtsoorten. Beschrijving, afbielding en determinatietabel. Meded. Proefst. Boschw. Batavia, No. 5, pp. 186; 1920.

168. Beijer, J. D. Die Vermehrung der radialen Reihen im Cambium. Rec. Trav. bot. néerland. **24,** 631–786; 1927.

169. Benoist, R. Sur le bois de quelques Anonacées américaines. Bull. Soc. bot. Fr. **74,** 281–5; 1927.

170. —— Les bois de la Guyane française. Arch. Bot. **5,** 1–292; 1931.

171. —— Le *Plantago rigida* H.B.K. sa structure, sa biologie. Bull. Soc. bot. Fr. **82,** 604–9; 1935.

172. —— L'*Espeletia Hartwegiana* Cuatr. Bull. Soc. bot. Fr. **83,** 279–85; 1936.

173. Benson, M. Root parasitism in *Exocarpus*, with comparative notes on the haustoria of *Thesium*. Ann. Bot. Lond. **24,** 667–77; 1910.

174. Bentley, N. J., and Wolf, F. A. Glandular leaf hairs of oriental tobacco. Bull. Torrey bot. Cl. **72,** 4. 345–60; 1945.

175. Berckemeyer, W. Über kontraktile Umbelliferenwurzeln. Bot. Arch. **24,** 273–318; 1929.

176. Berger, A. *Crassulaceae* in Engler & Prantl's *Die natürlich. Pflanzenfam.*, Auf. 2, 18a; 1930.

177. Berger, L. G. den. Determinatie-tabel van der voornaamste handelshoutsoorten van Malakka volgens het hout, naar aanleiding van F. W. Foxworthy's Commercial Woods of the Malay Peninsula, tevens een bespreking van dit werk. Tectona, **15,** 305–21; 1922.

178. —— Inleiding tot de herkenning van hout in de praktijk. Meded. Proefst. Boschw. Batavia, No. 7, pp. 55; 1922.

179. Berger, L. G. den. Houtsoorten der Culturgebieden van Java en van Sumatra's Oostkust. Meded. Proefst. Boschw. Batavia, No. 13, pp. 185; 1926.

180. —— Unterscheidungsmerkmale von rezenten und fossilen Dipterocarpaceengattungen. Bull. Jard. bot. Buitenz. **8,** 4. 495–8; 1927.

181. —— Beiträge zur Kenntnis der Anatomie des sekundären Holzes der Niederländisch-Indischen Baumarten. Bull. Jard. bot. Buitenz. **9,** 3/4. 223–48; 1928.

182. Berger, L. G. den, and Bianchi, A. T. J. Over het voorkomen van einige bijzondere kenmerken bij Nederlandsch-Indische Houtsoorten. Tectona, **24,** 894–903; 1931.

183. Berger, L. G. den, and Endert, F. H. Belangrijke houtsoorten van Nederlandsch-Indië. Meded. Proefst. Boschw. Batavia, No. 11, pp. 136; 1925.

184. Berger, M. G. *Étude Organographique, anatomique et pharmacologique de la famille des Turneracées.* Thesis, Paris, pp. 270; 1919.

185. Bergman, M. Vergleichende Untersuchungen über die Anatomie schweizerischer *Ranunculus*-Arten und deren Gehalt an Anemonol und Saponin. Ber. schweiz. bot. Ges. **54,** 400–522; 1944.

186. Besson, A. Richesse en cendres et teneur en silice des bois tropicaux. Agron. trop. Paris, **1,** 44–56; 1946.

Betts, M. W. Notes on the autecology of certain plants of the Peridotite Belt, Nelson: Part I—Structure of some of the plants.

187. No. 1: Trans. N. Zealand Inst. **50,** 230–43; 1918.

188. No. 2: Trans. N. Zealand Inst. **51,** 136–56; 1919.

189. No. 3: Trans. N. Zealand Inst. **52,** 276–314; 1920.

190. —— Notes from Canterbury College Mountain Biological Station, Cass. No. 7. The rosette plants, Part I. Trans. N. Zealand Inst. **52,** 253–75; 1920.

191. Beuzeville, W. A. W. de, and Welch, M. B. A description of a new species of *Eucalyptus* from Southern New South Wales. J. roy. Soc. N.S.W. **58,** 177–81; 1924.

192. Bews, J. W. Preliminary note on a peculiarity in the pith of a species of Cucurbit. Trans. bot. Soc. Edinb. **23,** 246–8; 1905.

193. —— Studies in the ecological evolution of the angiosperms. New Phytol. **26,** 1–21, 65–84, 129–48, 209–48, 273–94; 1927.

194. Bianchi, A. T. J. Nadere Gegevens ontrent ed aantasting van Nederlandisch-Indische Houtsoorten door paalworm en andere in zee- en brakwater levende dieren. Meded. Proefst. Boschw. Batavia, **25,** 100–47; 1932.

195. Biddulph, O. Histological variations in *Cosmos* in relation to photoperiodism. Bot. Gaz. **97,** 139–55; 1935.

196. Bider, J. *Beiträge zur Pharmakognosie der Boraginaceen und Verbenaceen. Vergleichende Anatomie des Laubblattes.* Thesis, Basel, pp. 124; 1935.

197. Bienfait, J. L., and Pfeiffer, J. Ph. A scheme for identification of woods with the aid of a hand lens. J. For. **22,** 724–61; 1924.

198. Bigalke, H. Die Blattspodogramme der Urticaceae und ihre Verwendbarkeit für die Systematik. Beitr. Biol. Pfl. **21,** 1–56; 1933.

199. Bird, J. W. Lianes of the ancient forest of Canterbury Plains. Trans. N. Zealand Inst. **48,** 315–53; 1915.

200. Birnstiel, W. *Vergleichende Anatomie der Cinnamomum Rinden.* Thesis, pp. 103; 1922.

201. Bitter, G. Die papuasischen Arten von *Solanum.* Bot. Jb. **55,** 59–113; 1919.

202. Blackwell, W. The histology of the callus tissue in *Althaea rosea.* New Phytol. **12,** 305–10; 1913.

203. Blank, F. Beitrag zur Morphologie von *Caryocar nuciferum* L. Ber. schweiz. bot. Ges. **49,** 437–94; 1939.

204. Blaque, G. Les plantes à thymol. Trav. Lab. Mat. méd. Paris, **5,** pp. 74; 1923.

205. Blaque, G., and Maheu, J. Les falsifications actuelles de l'*Hydrastis canadensis.* Bull. Sci. Pharm. **33,** 375–84; 1926.

206. BLASER, H. W. Anatomy of *Cryptostegia grandiflora*, with special reference to the latex system. Amer. J. Bot. **32,** 135–41; 1945.

207. BLISS, M. C. The vessel in seed plants. Bot. Gaz. **71,** 314–26; 1921.

208. BOAS, B. Beiträge zur Anatomie und Systematik der Simarubaceen. Beih. bot. Zbl. **29,** I. 303–56; 1912.

209. BOAS, F., and MERKENSCHLAGER, F. *Die Lupine als Objekt der Pflanzenforschung.* Thesis, Berlin, pp. 144; 1923.

210. BOBILIOFF, W. *Anatomy and physiology of Hevea brasiliensis. Part I. Anatomy of Hevea brasiliensis.* Zurich, 1923.

211. BODENSTAB, D. H. H. C. Die wichtigsten Gerbstoffspflanzen der Deutsch-Afrikanischen Schutzgebiete. Tropenpflanzer, **17,** 472–4, 619–31, 676–90; 1913.

212. BODMER, H. Beiträge zur Anatomie und Physiologie von *Lythrum salicaria* L. Beih. bot. Zbl. **45,** I. 1–58; 1928.

213. BOELMAN, H. A. C. Javaansche valeriaan. *See* Biol. Abstr. **15,** No. 24284; 1941.

214. BOER, M. H. W. DE. *Étude micrographique de dix drogues végétales nouvelles de la Pharmacopée-Néerlandaise.* Thesis, Paris, pp. 197; 1914.

215. BOESHORE, J. The morphological continuity of Scrophulariaceae and Orobanchaceae. Contr. bot. Lab. Univ. Pa. **5,** 139–77; 1920.

216. BOHMKER, H. Der Bau der extrafloralen und floralen Nektarien von *Passiflora coerulea* L. Beih. bot. Zbl. **33,** 193 and 207; 1917.

217. BOKE, N. H. Histogenesis and morphology of the phyllode in certain species of *Acacia.* Amer. J. Bot. **27,** 73–90; 1940.

218. —— Zonation in the shoot apices of *Trichocereus spachianus* and *Opuntia cylindrica.* Amer. J. Bot. **28,** 656–64; 1941.

219. —— Histogenesis of the leaf and areole in *Opuntia cylindrica.* Amer. J. Bot. **31,** 299–316; 1944.

220. —— Development of the adult shoot apex and floral initiation in *Vinca rosea.* Amer. J. Bot. **34,** 433–9; 1947.

221. BOLLE, F. *Resedaceae* in Engler & Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 17B; 1936.

222. BOLUS, H. M. L. *Notes on Mesembrianthemum.* Cape Town. 3 parts: I—pp. 156, II—pp. 520, III—pp. 188; 1928–39.

223. BOMBACIONI, V. Sopra alcune anomalie delle radici de *Vicia faba.* Ann. Bot. Roma, **16,** 244–54; 1924. *See* Bot. Zbl., N.S. **5,** 327; 1925.

224. BOND, G. The stem-endodermis in the genus *Piper.* Trans. roy. Soc. Edinb. **56,** 695–724; 1931.

225. —— The effect of malnutrition on root structure. Proc. roy. Soc. Edinb. **52,** 159–73; 1932.

226. —— The endodermis in light-grown and etiolated shoots of the Leguminosae: a contribution to the causal study of differentiation in the plant. Trans. roy. Soc. Edinb. **58,** 409–25; 1935.

BOND, T. E. T. Studies in the vegetative growth and anatomy of the tea plant (*Camellia thea* Link) with special reference to the phloem:

227. I. The flush shoot. Ann. Bot. Lond., N.S. **6,** 607–30; 1942.

228. II. Further analysis of flushing behaviour. Ann. Bot. Lond., N.S. **9,** 183–215; 1945.

229. BONNET, E. *Essai d'une monographie des Canellées.* Thesis, Paris, pp. 64; 1876.

230. BONNET, E. E. *Observations sur la structure anatomique de la tige des Paronychiées et des Caryophyllées.* Thesis, Paris, 1908. *See* Just's Jber., Pt. 1, 454; 1908.

231. BOODLE, L. A. Lignification of phloem in *Helianthus.* Ann. Bot. Lond. **20,** 319–21; 1906.

232. —— On the occurrence of different types of hair in the wallflower. Ann. Bot. Lond. **22,** 714–16; 1908.

233. —— The root and haustorium of *Buttonia natalensis.* Kew Bull. No. 6, 240–2; 1913.

234. Boodle, L. A. On the trifoliate and other leaves of the gorse (*Ulex europaeus* L.). Ann. Bot. Lond. **28,** 527–30; 1914.

235. —— The mode of origin and the vascular supply of the adventitious leaves of cyclamen. Ann. Bot. Lond. **34,** 431–7; 1920.

236. —— The bacterial nodules of the Rubiaceae. Kew Bull. No. 9, 346–8; 1923.

237. Boodle, L. A., and Worsdell, W. C. On the comparative anatomy of the Casuarineae with special reference to the Gnetaceae and Cupuliferae. Ann. Bot. Lond. **8,** 231–64; 1894.

238. Borm, L. Die Wurzelknöllchen von *Hippophaë rhamnoides* und *Alnus glutinosa.* Bot. Arch. **31,** 441–88; 1931.

239. Bottomley, W. B. The structure and physiological significance of the root nodules of *Myrica gale.* Proc. roy. Soc. B, **84,** 215–16; 1911.

240. —— The root nodules of *Myrica gale.* Ann. Bot. Lond. **26,** 111–17; 1912.

241. —— The root nodules of *Ceanothus americanus.* Ann. Bot. Lond. **29,** 605–10; 1915.

242. Bottum, F. R. Histological studies on the root of *Melilotus alba.* Bot. Gaz. **103,** 132–45; 1941.

243. Boulay, A. Contribution à l'étude des Apocynacées toxiques. Trav. Lab. Mat. méd. Paris, **16,** pp. 117; 1925.

244. Boulger, G. S. *Wood: a manual of the natural history and industrial applications of the timbers of commerce.* London, pp. 348; 1908.

245. Boulton, E. H. B., and Price, T. J. Notes on iroko (*Chlorophora excelsa*). Trop. Woods, **28,** 4–7; 1931.

246. Bournot, K. Gewinnung von Lapachol aus dem Kernholz von *Avicennia tomentosa.* Arch. Pharm. Berl. **251,** 351–541; 1913.

247. Bouvrain, G. Au sujet de quelques acquisitions nouvelles sur l'ontogénie des dicotylédons. Ann. Sci. nat. b., Sér. 11, 1–73; 1942.

248. —— Sur un mode de réduction du nombre des convergents dans la tige de *Bryonia dioica* (Cucurbitacées). Bull. Soc. bot. Fr. **90,** 172–6; 1943.

249. —— Nouveau mode de réduction massive du nombre des convergents. Bull. Soc. bot. Fr. **91,** 80–5; 1944.

250. Bowman, H. H. M. Mechanical tissue development in certain North American vines. Bull. Torrey bot. Cl. **41,** 365–72; 1914.

251. —— Ecology and physiology of the red mangrove. Proc. Amer. phil. Soc. **56,** 589–672, 1917. *See* Just's Jber., Pt. 1, 315; 1920.

252. —— Histological variations in *Rhizophora Mangle.* Rep. Mich. Acad. Sci. **22,** 129–34; (1920) 1921. *See* Just's Jber., Pt. 2, 69; 1921.

253. Braendlein, H. *Systematisch-anatomische Untersuchung des Blattes der Samydaceen Bentham-Hooker.* Thesis, Erlangen, pp. 70; 1907.

254. Brand, A. *Polemoniaceae* in Engler's *Das Pflanzenreich,* iv. 250; 1907.

255. —— *Hydrophyllaceae* in Engler's *Das Pflanzenreich,* iv. 251; 1913.

256. Brandscheit, P. Zur Anatomie und Entwicklungsgeschichte von *Chaerophyllum aureum* L. insbesondere seiner Achselgelenke. Beih. bot. Zbl. **40,** 1. 14–136; 1923.

257. Brand, A. *Borraginaceae-Borraginoideae-Cynoglosseae* in Engler's *Das Pflanzenreich,* iv. 252; 1921.

258. —— *Borraginaceae-Borraginoideae-Cryptantheae* in Engler's *Das Pflanzenreich,* iv. 252; 1931.

259. Brandt, W. *Zur Anatomie und Chemie der Ruta Graveolens* L. Thesis, Berlin, pp. 33; 1915. *See* Just's Jber., Pt. 1, 510; 1915.

260. —— Monographie der Gattungen *Corynanthe* Welwitsch und *Pausinstalia.* Über die Stammpflanze der Yohimberinden und ihre Verwandten. Arch. Pharm. Berl. **260,** 49–94; 1922.

261. —— Anatomische Untersuchung der Nolanaceen Gattungen *Alona* Lindl. und *Dolia* Lindl. Bot. Jb. **69,** 149–219; 1938.

262. Brandza, G. Recherches anatomiques sur la germination des Hypericacées et des Guttifères. Ann. Sci. nat. b., Sér. 9, **8**, 221–300; 1908. *See* Just's Jber., Pt. 1, 454; 1908.

263. Brattsten, I. Stammens och bladets anatomiska byggnad hos *Plantago fernandezia* Bert. och *P. pachyphylla* Gray. (English summary). Acta Hort Göteborg, **16**, 165–84; 1945.

264. Braun, E. *Zur Pharmakognosie der Ericaceen und Primulaceen. Anatomie des Laubblattes.* Thesis, Basel, 1933. *See* Arch. Pharm. Berl. **271**, 401; 1933.

265. Braun, K. *Beiträge zur Anatomie der Adansonia digitata* L. Thesis, Basel, pp. 56; 1900.

266. —— Der Affenbrotbaum (*Adansonia digitata* L.) und seine Verwendung besonders als Faserpflanze in Deutsch-Ostafrika. Faserforschung **8**, 359–92; 1929/30.

267. Bremerkamp, C. E. B. Controversial questions in taxonomy, I. Chronica bot. **7**, 255; 1942.

268. Bretin, J. *L'adonis vernalis et ses falsifications actuelles. Étude de matière médicale.* Thesis, Lyons, pp. 115; 1922. *See* Bull. Soc. bot. Fr. **69**, 899; 1922.

269. Brierley, W. G. Cambial activity in the red raspberry cane in the second season. Proc. Amer. Soc. hort. Sci. 278–80; 1929.

270. Bright, D. N. E. The effects of exposure upon the structure of certain heath plants. J. Ecol. **16**, 323–66; 1928.

271. Briquet, J. Sur la structure foliaire et les affinités des *Saxifraga moschata* Wulf et *exarata* Vill. Ann. Cons. Jard. Bot. Genève, **18/19**, 207–14; (1914–16), 1915. *See* Just's Jber., Pt. 1, 511; 1915.

272. —— La structure foliaire des *Hypericum* à feuilles scléro-marginées. C. R. Soc. Phys. Hist. nat. Genève, **36**, 75–9; 1919. *See* Just's Jber., Pt. 1, 233; 1920.

273. —— Sur l'organization et l'édaphisme des feuilles éricoides chez le *Pertya phylicoides* Jeffrey. C. R. Soc. Phys. Hist. nat. Genève, **37**, 15–19; 1920. *See* Just's Jber., Pt. 1, 257; 1920.

274. British Honduras Forest Department. *Notes on forty-two secondary hardwood timbers of British Honduras.* Bull. For. Dept. Brit. Honduras, No. 1, pp. 116; 1946.

275. Britton, N. L., and Rose, J. H. *The Cactaceae.* 4 vols. Washington, 1937.

276. Brocardet, P. Contribution à l'étude des plantes utiles de Brézil. Trav. Lab. Mat. méd. Paris, **13**, pp. 144; 1921.

277. Brogli, B. *Beiträge zur Anatomie der Myrtaceen Rinden.* Thesis, Basel, pp. 84; 1926.

278. Brooks, R. M. Comparative histogenesis of vegetative and floral apices in *Amygdalus communis* with special reference to the carpel. Hilgardia, **13**, 5. 249–99; 1940.

279. Brown, A. B. Cambial activity, root habit and sucker shoot development in two species of poplar. New Phytol. **34**, 163–79; 1935.

280. Brown, F. B. H. Scalariform pitting a primitive feature in angiospermous secondary wood. Science, **48**, 16–18; 1918.

281. —— The origin of the Hawaiian flora. Spec. Publ. Bishop Mus. Honolulu, **7**, 131–42; 1921.

282. —— The secondary xylem of Hawaiian trees. Occ. Pap. Bishop Mus. Honolulu, **8**, 6. 1–157; 1922.

283. —— Cornaceae and its allies in the Marquesas and the neighbouring islands. Bull. Bishop Mus. Honolulu, **52**, 1–52; 1928.

284. Brown, H. P. *Pith-ray flecks in wood.* Circ. U.S. Div. For., 215; pp. 15; 1913.

285. —— *An elementary manual on Indian wood technology.* Calcutta, pp. 121; 1925.

286. —— *Atlas of the commercial woods of the United States.* New York State Coll. For. Bull. 18 (**1**, No. 4), 60 plates; 1928.

287. —— *Commercial timbers of the United States.* New York, pp. 554; 1940.

288. Brown, H. P., and Panshin, A. J. *Das Holz der forstlich wichtigsten Bäume Mitteleuropas.* Hanover, pp. 23; 1932.

289. —— *Identification of the commercial timbers of the United States.* New York, pp. 223; 1934.

290. Brown, J. G. Subcortical formation and abnormal development of stomata in etiolated shoots of *Opuntia blakeana.* Bot. Gaz. **70,** 295–307; 1920.

291. Brown, N. E. Numerous short articles on *Mesembryanthemum* in Gdnrs' Chron. 1925–35.

292. —— *Rhopalota aphylla* N. E. Brown Crassulaceae. Icones Plantarum, Ser. 5, **2,** 3171; 1933.

293. Brown, N. E., Tischer, A., and Karsten, M. C. *Mesembryanthemata.* Ashford, Kent, pp. 323; 1931.

294. Brown, W. H. The relation of *Rafflesia manillana* to its host. Philipp. J. Sci. Sect. C. Bot. **7,** 209–26; 1912.

295. Brunner, C. Beiträge zur vergleichenden Anatomie der Tamaricaceae. Jb. Wiss. Anst. Hamburg, pp. 74; 1909. *See* Just's Jber., Pt. 1, 974; 1909.

296. Brunswick, H. Über das Vorkommen von Gipskristallen bei der Tamaricaceae. S.B. Akad. Wiss. Wien. Math.-Naturw. Kl. Abt. I, **129,** 115–36; 1920. *See* Just's Jber., Pt. 1, 233; 1920.

297. —— Über neuere Verfälschungen und Verschlechterungen von Drogen. VII. *Melissa officinalis* L. Z. allg. öst. ApothVer. **58,** 195–6 and 201–2; 1920. *See* Just's Jber., Pt. 1, 273; 1920.

298. Brush, W. D. The formation of mechanical tissue in the tendrils of *Passiflora coerulea* as influenced by tension and contact. Bot. Gaz. **53,** 453–77; 1912.

299. —— Distinguishing characteristics of the North American sycamore woods. Bot. Gaz. **64,** 480–96; 1917.

300. Bruyne, C. de. Idioplastes et diaphragmes des Nymphéacées. C. R. Acad. Sci. Paris, **175,** 452–5; 1922.

301. Bryce, G. On the formation of nodules in the cortex of *Hevea brasiliensis.* Ann. Roy. bot. Gdns. Peradeniya, **6,** 257–90; 1917.

302. Buch, H. O. *Beiträge zur Anatomie des Blattes pharmazeutisch gebräuchlicher Labiatendrogen.* Thesis, Basel, pp. 86; 1925. *See* Just's Jber., Pt. 2; 429; 1926.

303. Buchegger, J. Beitrag zur Systematik von *Genista Hassertiana*; *G. holopetala* und *G. radiata.* Öst bot. Z. **62,** 303–12; 1912.

304. Buchet, S. Sur le prétendu 'bois péripherique' des Ombellifères et sur l'abus des termes impropres en anatomie végétale. Bull. Soc. bot. Fr. **77,** 697–9; 1930.

305. Buder, J. Studien an *Laburnum adami.* II. Allgemeine anatomische Analyse des Mischlings und seiner Stammpflanzen. Z. indukt. Abstamm- u. Vererb.-Lehre, **5,** 209–84; 1911. *See* Just's Jber., Pt. 2, 1076; 1911.

306. Bugnon, P. L'organization libéroligneuse des cotylédons et de l'hypocotyle expliquée par la théorie du raccord chez la Mercuriale (*Mercurialis annua* L.). Bull. Soc. linn. Normandie, Sér. 7, **5,** 69–106; 1922.

307. Bukvic, N. Die thylloiden Verstopfungen der Spaltöffnungen und ihre Beziehungen zur Korkbildung bei den Cactaceen. Öst. bot. Z. **62,** 401–6; 1912.

308. Bulgakov, S. W. Modified anatomical structure in kok-saghyz roots and its biological import. C. R. Acad. Sci. U.R.S.S. **45,** 35–8; 1944. *See* Biol. Abstr. 20, No. 10935; 1946.

309. Bunton, L. Histology of *Townsendia exscapa* and *Lesquerella spathulata.* Kans. Univ. Sci. Bull. **5,** 183–205; 1910.

310. Burgerstein, A. Anatomische Untersuchungen samoanischer Hölzer. Denkschr. Akad. Wiss. Wien. Math.-Naturw. Kl. **84,** 455–58; 1908.

311. —— Diagnostiche Merkmale der Markstrahlen von *Populus* und *Salix.* Ber. dtsch. bot. Ges. **29,** 679–84; 1911.

312. Burgerstein, A. Anatomische Untersuchungen argentinischer Hölzer des K. K. naturhistorischen Hofmuseums in Wien. Ann. K. K. naturhist. Hofmuseum Wien, **26,** 1–36; 1912.

313. —— Der anatomische Bau der Blätter von *Hydnophytum formicarium* Becc., *H. tortuosum* Becc. und *H. Guppyanum.* Denkschr. Akad. Wiss. Wien. Math.-Naturw. Kl. **139,** 622–24; 1914. *See* Just's Jber., Pt. 1, 869; 1914.

314. Burgess, C. E. An abnormal stem of *Lonicera periclymenum.* New Phytol. **14,** 233–40; 1915.

314a. Burkill, I. H. *A dictionary of the economic products of the Malayan Peninsula.* 2 vols., pp. 2402; 1935.

315. Burret, M. Beiträge zur Kenntnis der Tiliaceen. Notizbl. bot. Gart. Berl. **9,** 88. 592–880; 1926.

315a. Burtt-Davy, J. African 'Sandaleen' wood. Trop. Woods, **17,** 15–17; 1928.

316. Buscaglioni, L. Studi sui cristalli di ossalato di calcio. Malpighia, **10,** 3–67 and 125–67; 1896.

317. Buscalioni, L. Sulle radici aeree fasciate di *Carallia integerrima* D. C. Malpighia, **29,** 81–96; 1921.

318. Buscalioni, L., and Catalano, G. Morfologia ed anatomia dei fillodi di *Acacia.* Boll. Soc. Sci. nat. econ. Palermo, n.s. **6,** 66–70; 1924.

319. —— Il legno crittogamico e la costituzione arcaica dei fillomi delle *Acacia* fillodiniche o fillodopodiche. G. Sci. nat. econ. Palermo, **34,** 3–9; 1925.

320. Buscalioni, L., and Muscatello, G. Sulle radici avventizie nell' interno del fusto del *Rhus viminalis* Ait. e su algune alterazioni del sistema radicale di questa specie. Malpighia, **23,** 447–69; 1909.

321. —— Studio anatomo-biologico sul gen '*Saurauia*' Willd. con speciale riguardo alle specie Americane. Malpighia, **26–30;** 1913–27.

322. Busch, P. Die Mahoganisorten des Handels. Tropenpflanzer, **15,** 479–93; 1911.

323. —— *Anatomisch-systematische Untersuchung der Gattung Diospyros.* Thesis, Erlangen, pp. 94; 1913.

324. Butler, O. Gummosis of *Prunus* and *Citrus.* Ann. Bot. Lond. **25,** 107–53; 1911.

325. Buttrick, P. L. Note on Brazilian cork. Trop. Woods, **68,** 11–13; 1941.

326. Byl, P. A. van de. The anatomy of *Acacia mollissima* Witd. with special reference to the distribution of tannin. S. Africa, Dep. Agric. Div. Bot. Sci. Bull. **3,** 3–32; 1914. *See* Bot. Zbl. **128,** 209; 1915.

327. Cain, S. A., and Oliver Miller, J. D. Leaf structure of *Rhododendron catawbiense* Michx. grown in *Picea abies* forest and in heath communities. Amer. Midl. Nat. **14,** 69–82; 1933.

328. Cain, S. A., and Potzger, J. E. A comparison of leaf tissues of *Gaylussacia baccata* (Wang.) C. Koch. and *Vaccinium vacillans* Kolm. grown under different conditions. Amer. Midl. Nat. **14,** 97–112; 1933.

329. Calvet, L.-E. *Contribution à l'histoire botanique des Kapokiers et à l'utilisation de leur produits.* Thesis, Montpellier, pp. 153; 1907.

330. Cameron, D. An investigation of the latex systems in *Euphorbia marginata* with particular attention to the distribution of latex in the embryo. Trans. bot. Soc. Edinb. **32,** 187–94; 1936.

331. Cammerloher, H. Der Spaltöffnungsapparat von *Brugmansia* und *Rafflesia.* Öst bot. Z. **69,** 153–64; 1920.

332. Camp, W. H. Our changing generic concepts. Bull. Torrey bot. Cl. **67,** 381–9; 1940.

333. —— The herbarium in modern systematics. Amer. Midl. Nat. **77,** 322–44; 1943.

334. —— The North American blueberries with notes on other groups of Vacciniaceae. Brittonia N.Y. **5,** 203–75; 1945.

335. Campbell, D. H. The phylogeny of the angiosperms. Bull. Torrey bot. Cl. **55,** 79–479; 1928.

336. Campbell, W. G., and Fisher, R. C. The composition and origin of 'stone' in iroko wood (*Chlorophora excelsa* Benth. and Hook f.). Emp. For. J. **11**, 2. 244–5; 1932.

337. Campion, W. E. How to identify jarrah and karri by microscopic examination. Aust. For. J. **9**, 16–18; 1926.

338. —— The differentiation of the timbers of *Eucalyptus diversicolor*, *E. marginata* and *E. jacksoni*. Aust. For. J. **10**, 154–5; 1927.

339. Campredon, J. Études des propriétés physiques et mécaniques de quelques bois exotiques. III. Le bois d'Ailante (*Ailanthus glandulosa* Desf.). Ann. Ec. Eaux For. Nancy, **5**, 211–17; 1934.

340. Cant, C. M. Stem structure in the Maddenii series of rhododendrons. Trans. bot. Soc. Edinb. **32**, 287–90; 1937.

341. Carey, G. Comparative anatomy of leaves from species in two habitats around Sydney. Proc. Linn. Soc. N.S.W. **62**, 439–50; 1938.

342. Carlson, M. C. Comparative anatomical studies of Dorothy Perkins and American Pillar roses. I. Anatomy of canes. II. Origin and development of adventitious roots in cuttings. Contr. Boyce Thompson Inst. **5**, 313–30; 1933.

343. —— The formation of nodal adventitious roots in *Salix cordata*. Amer. J. Bot. **25**, 721–5; 1938.

344. Cartellieri, E. Absorptionssystems der *Rafflesia Brugmansia*. Bot. Arch. **14**, 284–304; 1926. *See* Just's Jber., Pt. 2, 431; 1926.

345. Casparis, P. Masticogna, eine interessante Verfälschung von *succus liquiritae*. Schweiz. ApothZtg. **62**, 121–6; 1925. *See* Just's Jber., Pt. 2, 532; 1926.

346. Chaillot, M. Sur la biologie et l'anatomie des Labiées à stolons souterrains. C. R. Acad. Sci. Paris, **155**, 589–92; 1912. *See* Just's Jber., Pt. 2, 799; 1912.

347. Chainaye, R. Monographie du 'Soliva anthemidifolia' R. Br. Mem. Acad. R. Belg. Cl. Sci. **8**, No. 12, pp. 33; 1926.

348. Chakravarty, H. L. Physiological anatomy of the leaves of Cucurbitaceae. Philipp. J. Sci. **63**, 4. 409–31; 1937.

349. Chalk, L. Growth of the wood of ash (*Fraxinus excelsior* L. and *F. oxycarpa* Willd.) and Douglas fir (*Pseudotsuga Douglasii* Carr.) Quart. J. For. **21**, 102–22; 1927.

350. —— Tracheid length, with special reference to Sitka spruce. Forestry, **4**, 7–14; 1930.

351. —— *The formation of spring and summer wood in ash and Douglas fir.* Oxford For. Memoirs, No. 10, pp. 48; 1930.

352. —— Multiperforate plates in vessels, with special reference to the Bignoniaceae. Forestry, **7**, 16–22; 1933.

353. —— *The distribution of the lengths of fibres and vessel members and the definition of terms of size.* Imperial Forestry Institute (Oxford) Paper, No. 2, pp. 12; 1936.

354. —— The phylogenetic value of certain anatomical features of dicotyledonous woods. Ann. Bot. Lond., n.s. **1**, 408–28; 1937.

355. —— A note on the meaning of the terms earlywood and latewood. Proc. Leeds phil. lit. Soc. **3**, 325–6; 1937.

356. —— Standardization of terms for vessel diameter and ray width. Trop. Woods, **55**, 16–23; 1938.

357. —— On the taxonomic value of the anatomical structure of the vegetative organs of the dicotyledons. 2. The taxonomic value of wood anatomy. Proc. Linn. Soc. Lond. **155**, 3. 214–18; 1944.

358. Chalk, L., and Chattaway, M. M. Perforated ray cells. Proc. roy. Soc. B, **113**, 82–92; 1933.

359. —— Measuring the length of vessel members. Trop. Woods, **40**, 19–26; 1934.

360. Chalk, L., Chattaway, M. M., Davy, J. Burtt, Laughton, F. S., and Scott, M. H. *Fifteen South African high forest timber trees.* Forest Trees and Timbers of the British Empire (Oxford), No. 3, pp. 103; 1935.

361. CHALK, L., and CHATTAWAY, M. M. Factors affecting dimensional variations of vessel members. Trop. Woods, **41**, 17–37; 1935.

362. —— Identification of woods with included phloem. Trop. Woods, **50**, 1–31; 1937.

363. CHALK, L., DAVY, J. BURTT, and DESCH, H. E. *Some East African Coniferae and Leguminosae.* Forest Trees and Timbers of the British Empire (Oxford), No. 1, pp. 68; 1932.

364. CHALK, L., DAVY, J. BURTT, DESCH, H. E., and HOYLE, A. C. *Twenty West African timber trees.* Forest Trees and Timbers of the British Empire (Oxford), No. 2, pp. 108; 1933.

365. CHALK, L., and RENDLE, B. J. *British hardwoods, their structure and identification.* Bull. For. Prod. Res. Lond., No. 3, pp. 53; 1929.

366. CHANDLER, B. *Deherainia smaragdina* Decne. Notes R. bot. Gdn. Edinb. **5**, 49–56; 1911. *See* Just's Jber., Pt. 2, 1044; 1911.

367. CHAPMAN, V. J. The morphology of *Avicennia nitida* Jacq. and the function of its pneumatophores. J. linn. Soc. (Bot.) Lond. **52**, 487–533; 1944.

368. CHATTAWAY, M. M. *Entandrophragma cylindricum.* Variations in vessel pattern. Emp. For. J. **10**, 263–5; 1931.

369. —— Proposed standards for numerical values used in describing woods. Trop. Woods, **29**, 20–8; 1931.

370. —— The wood of the Sterculiaceae. I. Specialization of the vertical wood parenchyma within the sub-family Sterculieae. New Phytol. **31**, 119–32; 1932.

371. —— Ray development in the Sterculiaceae. Forestry, **7**, 93–108; 1933.

372. —— Tile-cells in the rays of the Malvales. New Phytol. **32**, 261–73; 1933.

373. —— Anatomical evidence that *Grewia* and *Microcos* are distinct genera. Trop. Woods, **38**, 9–11; 1934.

374. —— Relation between fibre and cambial initial length in dicotyledonous woods. Trop. Woods, **46**, 16–20; 1936.

375. —— The wood anatomy of the Sterculiaceae. Philos. Trans. Roy. Soc. **228**, 313–66; 1937.

376. —— Unpublished data.

377. CHANDLER, R. Note on *Donatia Novae-zelandiae* Hook. f. Notes R. bot. Gdn. Edinb. **5**, 22. 43–7; 1911. *See* Just's Jber., Pt. 2, 1045; 1911.

378. CHATTERJI, N. K. Anatomical studies in a necrotic papaya (*Carica papaya* L.) plant. J. Indian bot. Soc. **22**, 41–50; 1943.

379. CHAUDHURI, H. Recherches sur la bactérie des nodosités radiculaires du *Casuarina equisetifolia.* Bull. Soc. bot. Fr. **78**, 447–52; 1931.

380. CHAUVEL, Fr. *Recherches sur la famille des Oxalidacées.* Thesis, Paris, pp. 205; 1903.

381. CHAUVEL, H. Les tannins végétaux et en particulier les écorces tannantes de Madagascar. Trav. Lab. Mat. méd. Paris, **18**, pp. 180; 1927.

382. CHEADLE, V. I. The occurrence of vessels in the Monocotyledoneae. Amer. J. Bot. **26** (Supplement to Pt. 10), 9S; 1939.

383. —— Investigations of the vascular system in the Monocotyledoneae. Year Book Amer. philos. Soc. 149–52; 1941.

384. —— The occurrence and types of vessels in the various organs of the plant in the Monocotyledoneae. Amer. J. Bot. **29**, 441–50; 1942.

385. —— The role of anatomy in phylogenetic studies of the Monocotyledoneae. Chronica bot. **7**, 253; 1942.

386. —— Vessel specialisation in the late metaxylem of the various organs in the Monocotyledons. Amer. J. Bot. **30**, 7. 484–90; 1943. *See* Biol. Abstr. **17**, No. 2476; 1943.

387. —— The origin and certain trends of specialisation of the vessel in the Monocotyledoneae. Amer. J. Bot. **30**, 11–17; 1943.

388. Cheadle, V. I. Specialisation of vessels within the xylem of each organ in the Monocotyledoneae. Amer. J. Bot. **31,** 81–92; 1944.

389. Cheadle, V. I., and Whitford, N. B. A discussion of some factors which influence the form of the vascular bundle in the Monocotyledoneae. Amer. J. Bot. **28** (Supplement to No. 10), 2S; 1941.

390. Chemin, E. Observations anatomiques et biologiques sur le genre *Lathraea.* Ann. Sci. nat. b., Ser. 10, **2,** 125–272; 1920.

391. Chevalier, A., and Normand, D. Forêts vierges et bois coloniaux. No. 143, Coll. 'Que sais-je?' Paris, pp. 127; 1946.

392. Chevalier, A., *et al.* L'Okoumé (*Aucoumea klaineana* Pierre). Assoc. Col.-Sci. et Comité Nat. des Bois Coloniaux, pp. 38; 1929.

393. Chibber, H. M. The morphology and histology of *Piper betle* Linn. (the betel-vine). J. linn. Soc. (Bot.), **41,** 357–83; 1912.

394. Chifflot, J. Sur les canaux sécréteurs de quelques Gesnéracées et en particulier de ceux de *Monophyllaea horsfieldii* R. Br. C. R. Acad. Sci. Paris, **168,** 525–7; 1919.

395. Chirtoiu, M. Remarques sur le *Symplocos Klotzschii* et les affinités des Symplocaceae. Bull. Soc. bot. Genève, Sér. 2, **10,** 350–61; 1918.

395a. —— Observations sur les *Lacistema* et la situation systématique de ce genre. Bull. Soc. bot. Genève, Sér. 2, **10,** 317–61; 1918.

396. Chittenden, F. J. The naming of garden plants. J. roy. hort. Soc. **70,** 179–83; 1945.

397. Chkhubianishvili, I. I. Histological investigation of the leaf of *Primula nivalis* Pall. and *Cerastium ovatum* Boiss. C. R. Acad. Sci. U.R.S.S. **23,** 488–90; 1939.

398. Chodat, L. Contribution à la géo-botanique de Majorque. Bull. Soc. bot. Genève, Sér. 2, **15,** 153–264; 1923.

Chodat, R., *et al.*

(and Vischer, W.). La végétation du Paraguay:

399. V. Malpighiacées. Bull. Soc. bot. Genève, Sér. 2, **9,** 55–88; 1917.

(and Vischer, W.)

400. VI. Podostemonacées. Bull. Soc. bot. Genève, Sér. 2, **9,** 165–96; 1917.

(and Vischer, W.)

401. IX. Urticiflores. Bull. Soc. bot. Genève, Sér. 2, **11,** 226–58; 1919.

(and Vischer, W.)

402. Ombellifères. Bull. Soc. bot. Genève, Sér. 2, **12,** 25–54; 1920.

(and Vischer, W.)

403. XI. Borraginacées. Bull. Soc. bot. Genève, Sér. 2, **12,** 157–72; 1920.

(and Rehfous, L.)

404. XIV. Amarantacées. Bull. Soc. bot. Genève, **18,** 247–94; 1926.

405. Chodat, R., and Carisso, L. La Myrmécophilie des *Cordia* de la section *Gerascanthus.* Bull. Soc. bot. Genève, Sér. 2, **12,** 172–200; 1920.

406. Cholodny, N. Über die vegetative Vermehrung von *Sempervivum soboliferum.* Beih. bot. Zbl. **40,** 1. 161–73; 1923 (1924).

407. Choquette, L. Contribution à l'étude du *Dirca palustris* L. ou bois de Plomb. Trav. Lab. Mat. méd. Paris, **17,** pp. 93; 1926. *See* Just's Jber., Pt. 2, 433; 1926.

408. Chorinsky, F. Vergleichend-anatomische Untersuchung der Haargebilde bei Portulacaceen und Cactaceen. Öst. bot. Z. **80,** 308–27; 1931.

409. Chowdhury, K. A. Sandalwood and its Indian substitutes. Indian For. **57,** 431–3; 1931.

410. —— *The identification of important Indian sleeper woods.* (Indian) For. Bull., No. 77, pp. 18; 1932.

411. —— *The identification of the commercial timbers of the Punjab.* (Indian) For. Bull., No. 84, pp. 70; 1934.

412. —— The so-called terminal parenchyma cells in the wood of *Terminalia tomentosa.* Nature, Lond. **133,** 215; 1934.

413. CHOWDHURY, K. A. Terminal and initial parenchyma cells in the wood of *Terminalia tomentosa* W. & A. New Phytol. **35**, 351–8; 1936.

—— The formation of growth rings in Indian trees:

414. I. Ind. For. Rec., Util. **2**, 1. 1–39; 1939.

415. II. Ind. For. Rec., Util. **2**, 2. 40–57; 1940.

416. III. Ind. For. Rec., Util. **2**, 3. 59–75; 1940.

417. —— *How to distinguish between the sapwood and heartwood of sal* (*Shorea robusta*). (Indian) For. Bull., No. 115, pp. 3; 1942.

—— How to identify timbers:

418. II. *Identification of timber for helves and tool handles.* Ind. For. Leaflet No. 25, 6–16; 1942.

419. III. *Timber for motor lorry bodies.* Ind. For. Leaflet No. 37, 17–29; 1943.

IV. *See under* GHOSH, S. S.

420. V. *Timbers for gun and rifle parts.* Ind. For. Leaflet No. 50, 61–5; 1943.

421. VI. *Timbers for camp furniture.* Ind. For. Leaflet No. 51, 67–73; 1945.

422. —— The identification of Burma commercial timbers. Ind. For. Rec. (N.S. Util.), **3**, 6. 1–27; 1945.

423. —— Initial parenchyma cells in dicotyledonous woods. Nature, Lond., No. 4070, 609; 1947.

424. CHURCH, A. H. *Thalassiophyta and the subaerial transmigration.* Botanical Memoirs, No. 3, pp. 92; Oxford, 1919.

425. CLARKE, S. H. On the relationship between vessel size and Lyctus attack in timber. Forestry, **2**, 47–52; 1928.

426. —— *Home grown timbers. Elm.* Bull. For. Prod. Res. Lond., No. 7, pp. 27; 1930.

427. —— On estimating the mechanical strength of the wood of ash (*Fraxinus excelsior* L.). Forestry, **7**, 26–31; 1933.

428. —— *Gurjun, apitong, keruing, kapur and allied timbers.* For. Prod. Res. Rec., No. 16, pp. 11; 1937.

429. —— A comparison of certain properties of temperate and tropical timbers. Trop. Woods, **52**, 1–11; 1937.

430. —— Fine structure of the plant cell wall. Nature, Lond. **142**, 3603. 899–904; 1938.

431. CLAUSEN, B. J. Histology of *Janusia gracilis.* Kans. Univ. Sci. Bull. **7**, 189–97; 1913.

432. CLAUSEN, J., KECK, D. D., and HIESEY, W. M. *Experimental studies on the nature of species. I. Effect of varied environments on Western North American plants.* Carnegie Inst. Washington Publication No. 520, pp. vii and 452; 1940.

433. CLOS, D. Des glandes dans le genre *Hypericum.* Mem. Acad. Sci. Toulouse, **6**, 6. 257–66; 1868.

434. COCKRELL, R. A. Sclerosed tyloses of *Elateriospermum tapos* Bl. Pap. Mich. Acad. Sci. **20**, 31–2; 1935.

435. —— The wood anatomy of the North Sumatran Djeroek oetan, a supposed new genus of Rutaceae allied to *Murraya.* Pap. Mich. Acad. Sci. **20**, 33–6; 1939.

436. —— A comparative study of the wood structure of several South American species of *Strychnos.* Amer. J. Bot. **28**, 32–41; 1941.

437. —— An anatomical study of eighty Sumatran woods. Univ. Microfilm Publ. 384; 1942.

438. COCKRELL, R. A., and MONACHINO, J. Supplementary notes on Cockrell's study of the wood structure of *Strychnos.* Amer. J. Bot. **34**, 44; 1947.

439. COCKERHAM, G. Some observations on cambial activity and seasonal starch content in sycamore (*Acer Pseudoplatanus* L.). Proc. Leeds phil. lit. Soc. **2**, 64–80; 1930.

440. COFMAN-NICORESTI, J., and TALLANTYRE, S. B. An examination of Quillaia bark and commercial saponins. Pharm. J. **105**, 94–7; 1920.

441. Cogniaux, A. *Cucurbitaceae, Fevilleae et Melothriae* in Engler's *Das Pflanzenreich*, iv. 275. 1; 1916.

442. Cohen, W. E. *The identification of wood by chemical means.* Tech. Pap. For. Prod. Res. Aust., No. 15, pp. 23; 1935.

Cohen, W. E., *et al.*

(with Baldock, A. L., and Charles, A. G.). *The chemistry of Australian timbers:*

443. II. *The chemical composition of the woods of the ironbark group.* Tech. Pap. For. Prod. Res. Aust., No. 4, pp. 36; 1932.

(with Charles, A. G., and Jamieson, A. B.)

444. III. *The chemical composition of four pale-coloured woods of the genus Eucalyptus:—E. gigantea, E. obliqua, E. regnans, E. sieberiana.* Tech. Pap. For. Prod. Res. Aust., No. 9, pp. 22; 1933.

445. Col, M. Sur les fasicules, libériens anormalement placés dans les feuilles des Gentianées. C.R. Congres. Soc. Sav. 58–67; 1911. *See* Just's Jber., Pt. 2, 1060; 1913.

446. Colas, R. Les plantes amazoniennes designées sous le nom de 'Chuchuhuasha'. Trav. Lab. Mat. méd. Paris, **28,** 5, pp. 134; 1937.

447. Collardet, J. Les bois du Banlang. Rev. int. Prod. col. **4,** 17–22; 1919.

448. —— Okoumé (*Aucoumea klaineana* Pierre). Trop. Woods, **17,** 1–5; 1929.

449. —— Bossé (*Guarea cedrata*). Trop. Woods, **20,** 10–14; 1929.

450. —— Les acajous. Les Khaya sont-ils des acajous? Act. C.R. Ass. Col.-Sci., Nos. 62–3; 1930.

451. Collins, M. I. On the structure of the resin-secreting glands in some Australian plants. Proc. Linn. Soc. N.S.W. **45,** 329–36; 1920.

452. —— On the leaf anatomy of *Scaevola crassifolia*, with special reference to the epidermal secretion. Proc. Linn. Soc. N.S.W. **43,** 247–59; 1918.

453. Colozza, A. Studio anatomico sulle 'Goodeniaceae'. Nuovo G. bot. Ital. **15,** 5–92; 1908.

454. —— Note anatomiche sulla Calyceraceae. Bull. Soc. bot. Ital. 7–14; 1909. *See* Just's Jber., Pt. 2, 1588; 1910.

455. —— Studio anatomico sulle Turneraceae. Nuovo G. bot. Ital. **20,** 559–601; 1913. *See* Just's Jber., Pt. 2, 1060; 1913.

456. Compton, R. H. The anatomy of the Mummy Pea. New Phytol. **10,** 249–55; 1911.

457. Conard, H. S. *The water lilies.* Washington, pp. 279; 1905.

458. Cooke, F. W. Observations on *Salicornia australis.* Trans. N. Zealand Inst. **44,** 349–62; 1912.

459. Cooper, D. C. The development of the peltate hairs of *Shepherdia canadensis.* Amer. J. Bot. **19,** 423–8; 1932.

460. Cooper, G. P. Espavé (*Anacardium Rhinocarpus* DC.). Trop. Woods, **22,** 4–9; 1930.

461. Cooper, G. P., and Record, S. J. *The evergreen forests of Liberia.* Bull. Yale Sch. For., No. 31, pp. 153; 1931.

462. Cooper, T. B. A study of the pericycle in the Caprifoliaceae. Trans. bot. Soc. Edinb. **32,** 548–55; 1938.

463. Cooper, W. S. *The Broad-sclerophyll vegetation of California, an ecological study of the Chaparral and its related communities.* Carnegie Inst. Washington Publ. 319, pp. 124; 1922.

464. Copeland, H. F. The structure of *Monotropis* and the classification of the Monotropideae. Madroño, S. Francisco, **5,** 105–19; 1939.

465. —— Observations on the structure and classification of the Pyroleae. Madroño, S. Francisco, **9,** 3. 65–105; 1947.

466. Copeland, H. F., and Doyel, B. E. Features of the structure of *Toxicodendron diversiloba.* Amer. J. Bot. **27,** 932–9; 1940.

467. Cordemoy, H. J. de. Observations anatomiques sur les Clusiacées du Nord-

Ouest de Madagascar (influence du milieu sur les variations de leur appareil sécréteur). Ann. Sci. nat. b., Sér. 9, **11**, 287–359; 1910.

468. Cordemoy, H. J. de. Recherches anatomiques sur les Mélastomacées du Nord-Ouest de Madagascar. Ann. Sci. nat. b., Sér. 9, **14**, 281–344; 1911.

469. —— De l'influence du milieu et en particulier du terrain sur les variations de l'appareil sécréteur et de la sécrétion résineuse des Clusiacées. Bull. Soc. linn. Provence, **3**, 111–17; 1911.

470. —— Sur la structure de deux Mélastomacées épidendres à racines tuberisées de l'Est de Madagascar. C. R. Acad. Sci. Paris, **154**, 1523–5; 1912. *See* Just's Jber., Pt. 2, 799; 1912.

471. —— Observations anatomiques sur les *Gravesia* de Madagascar. Rev. gén. Bot. **25**, *bis*, 373–90; 1914.

472. —— Recherches anatomiques sur les *Medinilla* de Madagascar. Ann. Sci. nat. b., Sér. 9, **18**, 67–145; 1914.

473. —— Contribution à l'étude de la morphologie, de l'anatomie comparée, de la phylogénie et de la biogéographie des Casuarinacées. Rev. gén. Bot. **35**, 71–91, 127–40, 186–95, 227–43, 292–303, 335–47, 399–413; 1923.

474. Cormio, R. L'*Avicennia marina* dell' Oltre Giuba. Lignum, Milan, **17**, Nos. 5–6, pp. 11; 1939.

475. —— Monografia sui ciocchi di *Erica arborea* di Eritrea e di Calabrica. L'Ingegnere (Milan), Aug.–Sept., pp. 26; 1943.

476. Correns, C. Untersuchungen über die Gattung *Cerastium*. I. Die Verwertung der Haarformen für die Unterscheidung der Arten. Öst. bot. Z. **59**, 169–83; 1909.

477. Cortesi, R. Contribution à l'anatomie des pétioles d'*Acer*. Ber. schweiz. bot. Ges. **53**, 102–13; 1943.

478. Coster, C. Die physiologische und pathologische Kernholzbildung bei *Tectona grandis* L. f. nebst Bemerkungen über die Bildung des Wundholzgummis. Ann. Jard. bot. Buitenz. **34**, 1–15; 1925.

479. —— Eine Missbildung des Stammes von *Tectona grandis* L. f. Ann. Jard. bot. Buitenz. **35**, 120–4; 1926.

480. —— Die Buche auf dem Gipfel des Pangerango. Ann. Jard. bot. Buitenz. **35**, 105–19; 1926.

481. —— Zur Anatomie und Physiologie der Zuwachszonen- und Jahresringbildung in den Tropen. Ann. Jard. bot. Buitenz. **37**, 49–160; 1927.

482. Cotton, A. D. The megaphytic habit in the tree Senecios and other genera. Proc. linn. Soc. Bot. **156**, 158–68; 1944.

483. Coulter, J. M. The relations of paleobotany to botany. I. Phylogeny and taxonomy. Amer. Nat. **46**, 215–25; 1912.

484. Courchet, C. Sur le *Protorhus perrieri* n. sp. de Madagascar. Ann. Inst. colon. Marseille, Sér. 2, **5**, 41–66; 1907. *See* Just's Jber., Pt. 1, 432; 1908.

485. —— Le Kitzongo vrai du Madagascar, *Rourea* (*Byrsocarpus*) *orientalis*. Ann. Mus. colon. Marseille, **15**, 1–69; 1908.

486. Cousins, S. M. The comparative anatomy of the stem of *Betula pumila*, *Betula lenta* and the hybrid *Betula jackii*. J. Arnold Arbor. **14**, 4. 351–5; 1933.

487. Coutant, M. W. Wound periderm in certain cacti. Bull. Torrey bot. Cl. **45**, 353–64; 1918.

488. Coutière-Trannoy, F., and Chevalier, G. Quelques différences de structure et d'anatomie entre deux variétés de Dahlias. Bull. Mus. Hist. nat. Paris, Sér. 2, **17**, 517–23; 1945.

489. Coverlid, A. M. The leaf of *Grewia polygama* and its tannin content. Proc. roy. Soc. Vict. **39**, 149–53; 1927.

490. Cox, M. J. The comparative anatomy of the secondary xylem of five American species of *Celtis*. Amer. Midl. Nat. **25**, 348–57; 1941.

491. Cozzo, D. La estructura estratificada del leño de *Capparis salicifolia* Gris. Ingenieria Agronomica (Buenos Aires), **6**, 151–3; 1944.

492. Cozzo, D. Anatomía del leño de *Cyclolepis genistoides* Don. Archivos Farmacea Bioquímica, Tucumán, **3**, 121–5; 1946.

493. —— Relación anatómica entre la estructura del leño de las especies argentinas de *Capparis* y *Atamisquea*. Lilloa, **12**, 29–37; 1946.

494. —— Los géneros de fanerogamas Argentinas con radios leñosos altos en su leño secundario. Rev. argent. Agron. (Buenos Aires), **13**, 207–30; 1946.

495. —— Estructura leñosa estratificada en el género '*Plectrocarpa*' (Zigofilaceas). Rev. argent. Agron. (Buenos Aires), **13**, 286–92; 1946.

496. Crafts, A. S. Phloem anatomy, exudation and transport of organic nutrients in cucurbits. Plant Physiol. **7**, 183–225; 1932.

497. —— Sieve tube structure and translocation in the potato. Plant Physiol. **8**, 81–104; 1933.

498. Crété, P. Recherches anatomiques sur le séminogenèse de l'*Actinidia chinensis* Planch. Affinités des Actinidiacées. Bull. Soc. bot. Fr. **91**, 153–60; 1944.

499. Crevost, Ch., and Reland. Notes sur les fibres de *Wrightia annamensis* Eber. et Dub. Bull. ècon. Indochine, **19**, 483–90; 1917.

500. Croizat, L. Three Amazonian species of *Phyllanthus* L. Trop. Woods, **78**, 5–9; 1944.

501. —— *Trochodendron*, *Tetracentron* and their meaning in phylogeny. Bull. Torrey bot. Cl. **70**, 60–76; 1947.

502. Crockart, I. B. The root system of *Ranunculus monspeliacus*. Trans. bot. Soc. Edinb. **32**, 415–23; 1939.

Cronquist, A. Studies in the Simarubaceae:

503. I. The genus *Castela*. J. Arnold Arbor. **25**, 122–8; 1944.

504. III. The genus *Simaba*. Lloydia (Cincinnati), **7**, 81–92; 1944. *See* Trop. Woods, **79**, 37; 1944.

—— Studies in the Sapotaceae:

505. I. The North American species of *Chrysophyllum*. Bull. Torrey bot. Cl. **72**, 191–204; 1945.

506. II. Survey of the North American genera. Lloydia, **9**, 241–92; 1946.

507. III. *Dipholis* and *Bumelia*. J. Arnold Arbor. **25**, 435–71; 1945.

508. Crooks, D. M. Histological and regenerative studies on the flax seedling. Bot. Gaz. **95**, 2. 209–39; 1933.

509. Cross, G. L. The morphology of the bud and the development of the leaves of *Viburnum rufidulum*. Amer. J. Bot. **24**, 266–76; 1937.

510. Cross, G. L., and Johnson, T. J. Structural features of the shoot apices of diploid and colchicine induced tetraploid strains of *Vinca rosea*. Bull. Torrey bot. Cl. **68**, 618–35; 1941.

511. Crossmann, K. F. Citrus roots. Their anatomy, osmotic pressure and periodicity of growth. Palestine J. Bot. **3**, 1–2: R. Ser. 65–104; 1940. *See* Expt. Stat. Record. **89**, 5. 526; 1943.

512. Cumming, N. M. Notes on strand plants. 1. *Atriplex Babingtonii* Woods. Trans. bot. Soc. Edinb. **29**, 171–5; 1925.

513. Cummings, K. Early development of the latex system in *Euphorbia* sp. Amer. J. Bot. **28**, 728; 1941.

514. Cummins, J. E. The pore size (vessel diameter) of some Australian timbers and their susceptibility to attack by the powder post borer (*Lyctus brunneus* Stephens). J. Coun. Sci. industr. Res. Aust. **7**, 225–33; 1934.

515. Cunningham, L. M. Observations on the structure of *Zygophyllum Fabago* Linn. Trans. bot. Soc. Edinb. **29**, 353–61; 1927.

516. Curtis, W. M. The structure and development of some apomicts of *Taraxacum*. Kew Bull. No. 1, 1–29; 1940.

517. —— Observations on the stem anatomy of the genus *Richea*. Pap. roy. Soc. Tasm. 33–4; 1940.

518. Dadswell, H. E. *The identification of wood by chemical means.* Tech. Pap. For. Prod. Res. Aust., No. 1, pp. 16; 1931.

519. —— *The density of Australian timbers. A preliminary study.* Tech. Pap. For. Prod. Res. Aust., No. 2, pp. 16; 1931.

520. —— *Properties of Australian timbers. Part I. Eight timbers of the genus Eucalyptus (Ash Group).* Tech. Pap. For. Prod. Res. Aust., No. 13, pp. 28; 1933.

521. —— Timbers of the New Guinea region. Trop. Woods, **83,** 1–14; 1945.

522. Dadswell, H. E., and Burnell, M. *Methods for the identification of the coloured woods of the genus Eucalyptus.* Tech. Pap. For. Prod. Res. Aust., No. 5, pp. 50; 1932.

523. Dadswell, H. E., Burnell, M., and Eckersley, A. M. *Methods for the identification of the light-coloured woods of the genus Eucalyptus.* Tech. Pap. For. Prod. Res. Aust., No. 12, pp. 60; 1934.

524. Dadswell, H. E., and Eckersley, A. M. A note on the wood structure of *Acradenia frankliniae* Kipp. J. Coun. Sci. industr. Res. Aust. **7,** 39–42; 1934.

525. —— *The identification of the principal commercial Australian timbers other than Eucalypts.* Tech. Pap. For. Prod. Res. Aust., No. 16, pp. 102; 1935.

526. —— *The wood structure of some Australian Rutaceae, with methods for their identification.* Tech. Pap. For. Prod. Res. Aust., No. 25, pp. 32; 1938.

527. —— *The wood structure of some Australian Cunoniaceae, with methods for their identification.* Tech. Pap. For. Prod. Res. Aust., No. 27, pp. 23; 1938.

528. —— *The wood anatomy of some Australian Lauraceae, with methods for their identification.* Tech. Pap. For. Prod. Res. Aust., No. 34, pp. 48; 1940.

529. —— *Some timber species of Papua and New Guinea, with descriptive notes on properties and uses and means of identification.* For. Prod. Res. Aust. Mimeo., 1943.

530. Dadswell, H. E., and Ellis, D. I. *The wood anatomy of some Australian Meliaceae, with methods for their identification.* Tech. Pap. For. Prod. Res. Aust., No. 31, pp. 20; 1939.

531. Dadswell, H. E., and Ingle, H. D. The wood anatomy of the Myrtaceae I. A note on the genera *Eugenia, Syzygium, Acmena,* and *Cleistocalyx.* Trop. Woods, **90,** 1–7; 1947.

532. Dadswell, H. E., and Langlands, I. Brittle heart in Australian timbers. A preliminary study. J. Coun. Sci. industr. Res. Aust., **7,** 190–6; 1934.

533. Dadswell, H. E., and Record, S. J. Identification of woods with conspicuous rays. Trop. Woods, **48,** 1–30; 1936.

534. Dale, E. Investigations on the abnormal outgrowths or intumescences on *Hibiscus vitifolius* Linn. Philos. Trans. Roy. Soc. Ser. B, **194,** 163–82; 1901.

535. Dallimore, W. Elms and elm timber. Quart. J. For. **14,** 109–18; 1920.

D'Almeida, J. F. R. A contribution to the study of the biology and physiological anatomy of Indian marsh and aquatic plants:

536. Part I. Malvaceae. J. Bombay nat. Hist. Soc. **42,** 298–304; 1941.

537. Part II. Elatinaceae. J. Bombay nat. Hist. Soc. **43,** 92–6; 1942.

538. Danila, J. *Recherches sur le développement de la structure anatomique de la tige du Tilia platyphyllos Scop.* Thesis, Lausanne, pp. 79; 1925. *See* Bot. Zbl., N.S. **7,** 196; 1927.

539. Danowitsch, N. D., and Krinkin, F. Ch. *Zur vergleichenden Histologie einiger früher, mittlerer und später Kartoffelsorten.* Bull. White. Russ. Lenin Inst. Sci. Research Agric. Forestr. Minsk, pp. 73; 1929. Russian with Russian and German summaries. *See* Bot. Zbl. **19,** 452; 1931.

540. Dantzer, J. Étude de la fibre du Lao dénommée 'Po Lom Pom' (*Thespesia Lampas* Dalz. et Gibs.). Agron. colon. Paris, **15,** 161–4; 1926.

541. Dastur, R. H. The origin and course of vascular bundles in *Achyranthes aspera* L. Ann. Bot. Lond. **39,** 539–45; 1925.

542. Dastur, R. H., and Saxton, W. T. A new method of vegetative multiplication in *Crotalaria Burhia* Ham. New Phytol. **20,** 228–33; 1921.

543. DASTUR, R. H., and SAXTON, W. T. The oecology of some plant communities in the Savannah formation. J. Indian bot. Soc. **3**, 34–50; 1922.

544. DATTA, S. C., and BAL, S. N. Pharmacognostic studies on *Lobelia nicotianaefolia* Heyne. Sci. & Culture, **10**, 260–1; 1944. *See* Biol. Abstr. **19**, No. 14394; 1945.

545. DAUMAN, E. Nektarien und Bienenbesuch bei *Opuntia monacantha* Haw. Biol. gen. **6**, 353–76; 1930.

546. DAUPHINÉ, A. De l'évolution de l'appareil conducteur dans le genre *Kalanchoë*. Ann. Sci. nat. b., Sér. 9, **15**, 153–63; 1912.

547. —— Description anatomique de quelques espèces du genre *Cotyledon*. Ann. Sci. nat. b., Sér. 9, **17**, 225–32; 1913.

548. —— Au sujet de travaux récents sur l'appareil conducteur des Phanérogames. Bull. Soc. bot. Fr. **83**, 285–7; 1936.

549. DAUPHINÉ, A., and HAMET, R. Contribution à l'étude anatomique du genre *Kalanchoë*. Ann. Sci. nat. b., Sér. 9, **14**, 195–219; 1911.

550. DAVIES, P. A. Origin and development of prickles of *Aralia spinosa*. Trans. Ky. Acad. Sci. **10**, 29; 1942. *See* Biol. Abstr. **18**, No. 1504; 1944.

551. —— Leaf glands on *Ailanthus altissima*. Trans. Ky. Acad. Sci. **12**, 31–3; 1945. *See* Biol. Abstr. **21**, 4, No. 9717; 1947.

552. DAVY, A. J. Note on the structure of the epicotyl in *Juglans nigra*. New Phytol. **34**, 201–10; 1945.

553. DEBBERMAN, P. M. Some observations on the anchoring pads of *Gymnopetalum cochinchinense* Kurz. and some other cucurbitaceous plants. J. Indian. bot. Soc. **3**, 52–7; 1922.

554. DE CANDOLLE, C. Piperaceae Novae e Micronesia et Polynesia allatae. Bot. Jb. **56**, 502–6; 1920.

555. DE FRAINE, E. The anatomy of the genus *Salicornia*. J. linn. Soc. (Bot.), **41**, 317–48; 1912.

556. —— The morphology and anatomy of the genus *Statice* as represented at Blakeney Point. Pt. I. *Statice binervosa* G. E. Smith and *S. bellidifolia* DC. (= *S. reticulata*). Ann. Bot. Lond. **30**, 239–82; 1916.

557. DEHAY, C. L'appareil libéro-ligneux foliaire des Euphorbiacées. Ann. Sci. nat. b., Sér. 10, **17**, 147–290; 1935.

558. —— L'appareil libéro-ligneux foliaire des Sterculiacées. Ann. Sci. nat. b., Sér. 11, **45**, 128; 1941.

559. —— Remarques sur l'appareil libéro-ligneux foliaire des Sterculiacées. Bull. Soc. bot. Fr. **89**, 76–8; 1942.

560. —— L'appareil libéro-ligneux foliaire des Tiliacées. Bull. Soc. bot. Fr. **91**, 27–9; 1944.

561. DELEVOY, M. G. *Études systématiques des bois du Katanga.* Brussels: Part I, pp. 24; II, pp. 37; III, pp. 36; IV, pp. 34; V, pp. 33; VI, pp. 35; VII, pp. 54; 1928.

562. DEMETER, K. Über 'Plasmostypen'-Mykorrhiza. Flora, Jena, **116**, 405–56; 1923.

563. DEMOUGEOT, M. Les bois de la Guyane Française. Le Manil et le Parcouril. Rev. int. Prod. colon. **109**, 19–24; 1935.

564. DENIS, M. Recherches anatomiques sur quelques plantes littorales de Madagascar. Rev. gén. Bot. **31**, 33–52, 115–20, 129–42; 1919.

565. —— Les Euphorbiées des îles australes d'Afrique. Rev. gén. Bot. **34**, 5–64, 171–7, 214–36, 287–99, 346–66; 1922.

566. DESCH, H. E. Anatomical variation in the wood of some dicotyledonous trees. New Phytol. **31**, 73–118; 1932.

567. —— 'Latex canals' of the Apocynaceae. Malayan Forester, **3**, 219; 1934.

—— Notes on Malayan timbers:

568. I. Malayan Forester, **3**, 90–102; 1934.

569. Desch, H. E. II. Malayan Forester, **3**, 138–47; 1934.

570. III. Malayan Forester, **3**, 191–202; 1934.

571. IV. Malayan Forester, **4**, 23–9; 1935.

572. —— *Timber, its structure and properties.* London, pp. 299; 1947.

573. —— Dipterocarp timbers of the Malay Peninsula. Malayan For. Rec., No. 14, pp. 171; 1941.

574. —— Manual of Malayan timbers. Malayan For. Rec., No. 15, Vol. 1, pp. 328; 1941.

575. Desch, H. E., and Symington, C. F. Commercial timbers of the Malay Peninsula. I. The genus *Shorea*. Malayan For. Rec., No. 12, pp. 73; 1936.

576. Descole, H. R., and O'Donell, C. A. Estudios anatómicos en el leño de plantàs tucumanas. Lilloa, **1**, 75–93; 1937.

577. —— La disposición estradificada de los elementos. Lilloa, **2**, 23–30; 1938.

578. Dewar, T. The histology of the leaves of *Digitalis thapsi*. Quart. J. Pharm. **6**, 443–53; 1933.

579. —— The histology of the leaves of *Digitalis lanata* Ehrh. Quart. J. Pharm. **7**, 331–45; 1934.

580. Dewar, T., and Wallis, T. E. Digitalis leaf. The macroscopical and microscopical characters, potencies and constituents of certain species. Pharm. J., Ser. 4, **81**, 565–6; 1935.

581. Dharmarajulu, K. A study of the pathological anatomy of the cotton plant in connection with the wilt disease. Indian J. Agric. Sci. **2**, 293–313; 1932.

582. Diehl, G. A. A study of the Lecythidaceae. Trop. Woods, **43**, 1–15; 1935.

582A. Diels, L. Diapensiaceen-Studien. Bot. Jb. Festband, **50**, 304–30; 1914.

583. —— Über die Gattung *Himantandra*, ihre Verbreitung und ihre systematische Stellung. Bot. Jb. **55**, 126–34; 1919.

584. —— *Cephalotaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 18A; 1930.

585. —— *Byblidaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 18A; 1930.

586. —— *Droseraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 17B; 1936.

587. Diepenbrock, F. Beiträge zur botanischen und pharmakognostischen Kenntnis von *Corolla illipis latifoliae*, *Radix Tribuli Cistoides*, *Rhizoma Araliae racemosae* und *Calyx Hibisci sabdariffa*. Angew. Bot. **10**, 1–66; 1928.

588. Diettert, R. A. The morphology of *Artemisia tridentata* Nutt. Lloydia, **1**, 3–74; 1938.

589. Dihm, H. Das Blatt der Gattung *Meliosma* (Sabiaceen) in anatomischer Hinsicht. Beih. bot. Zbl. **21**, 117–47; 1907.

590. D'Ippolito, G. Contributo all' anatomia comparata del caule delle Magnoliacee in relazione specialmente alla struttura anatomica del egno secondario. Malpighia, **15**, 438–60; 1902.

591. Dischendorfer, O. Über die Faser von *Asclepias syriaca* L. Angew. Bot. **8**, 281–9; 1926.

592. Dixon, H. H. Mahogany and the recognition of some of the different kinds by their microscopic characteristics. Sci. Proc. R. Dublin Soc. **34**, 431–86; 1910.

593. Djakonov, A. B. In connection to the question of the influence of external conditions on the number of fibres in the flax stem. J. Landw. Wiss. Moskau, **5**, 194–201; 1928.

594. Djordjevic. *Anatomischer Bau des Holzes und Anleitung zum Bestimmen unserer wichtigeren Holzarten und Sträucher nach ihren anatomischen Merkmalen.* Belgrade, 1931.

595. Domke, W. Untersuchungen über die systematische und geographische Gliederung der Thymelaeaceen nebst einer Neubeschreibung ihrer Gattungen. Bibl. bot. Stuttgart, **27**, pp. 149; 1934.

596. Dommel, H. C. Über die Spaltöffnungen der Gattung *Euphorbia*. Ber. dtsch. bot. Ges. **28**, 72–7; 1910.

597. Dop, P. Recherches morphologiques et anatomiques sur une Rubiacée nouvelle de Madagascar. La *Dirichletia Princei* n. sp. Ann. Inst. col. Marseille, Sér. 2, **5**, pp. 9; 1907. *See* Just's Jber., Pt. 1, 433; 1908.

598. —— Contribution à l'étude du genre *Premna* L. Bull. Soc. bot. Fr. **70**, 437–46 and 829–36; 1923.

599. Dormann, F. Zur Kenntnis der Hautdrüsen und der Harzexkretion von *Alnus viridis*. S. B. Akad. Wiss. Wien, **133**, 585–612; 1924. *See* Just's Jber. 339; 1924.

600. Dormer, K. J. Some examples of correlation between stipules and lateral leaf traces. New Phytol. **43**, 151–3; 1944.

601. —— An investigation of the taxonomic value of shoot structure in angiosperms with especial reference to Leguminosae. Ann. Bot. Lond., n.s. **9**, 141–53; 1945.

602. —— On the absence of a plumule in some leguminous seedlings. New Phytol. **44**, 25–8; 1945.

603. —— Morphology of the vegetative shoot in the Epacridaceae. New Phytol. **44**, 149–51; 1945.

604. —— Anatomy of the primary vascular system in dicotyledonous plants. Nature, Lond. **158**, 737–9; 1946.

605. —— Vegetative morphology as a guide to the classification of the Papilionatae. New Phytol. **45**, 145–61; 1946.

606. Dörries, W. Bemerkungen über anormales Dickenwachstum der Lianen nebst einer Bestimmungstabelle nach den Stämmen der Göttinger Sammlung. Jber. Naturhist. Ges. Hannover, **60** and **61**, 83–98; 1912. *See* Just's Jber., Pt. 2, 1063; 1913.

607. Dorsey, M. J., and Weiss, F. Petiolar glands in the plum. Bot. Gaz. **69**, 391–406; 1920.

608. Douglas, G. E. Studies in the vascular anatomy of the Primulaceae. Amer. J. Bot. **23**, 3. 199–212; 1936.

609. Doyle, J. Some researches in experimental morphology. (i) On the change of the petiole into a stem by means of grafting. Sci. Proc. R. Dublin Soc., n.s. **14**, 405–44; 1915.

610. Drude, O. *Die Epacridaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iv; 1889.

611. Dubard, M., and Dop, P. Description de quelques espèces nouvelles de Madagascar. Bull. Soc. bot. Fr. **54**, 155–70; 1907.

612. —— Nouvelles observations sur l'anatomie et les affinités des Malpighiacées de Madagascar. C. R. Acad. Sci. Paris, **146**, 355–7; 1908. *See* Just's Jber., Pt. 1, 434; 1908.

612a. Duchesne, F. Étude sur les bois de trois Méliacées du Congo Belge. Rev. Zool. Bot. afr. **19**, 131–49; 1930.

612b. —— La structure du bois de l'arbre a vernis. Rev. Zool. Bot. afr. **23**, 41–51; 1932.

613. Ducke, A. *Lonchocarpus*, subgenus *Phacelanthus* Pittier in Brazilian Amazonia. Trop. Woods, **69**, 2–7; 1942.

614. Duncan, J. F. 'Pull Roots' of *Oxalis esculenta*. Trans. bot. Soc. Edinb. **29**, 192–6; 1925.

615. Duncan, W. H. Ecological comparison of the leaf structure of *Rhododendron punctatum* Andr. and the ontogeny of epidermal scales. Amer. Midl. Nat. **14**, 83–95; 1933.

616. Dunckter, B. J. J. Bau und sekundares Dickenwachstum von Krautpflanzen mit interfaszikularkambium. Rec. Trav. bot. néerland, **33**, 2. 586–644; 1936.

617. Dunn, S. T. *Dipentodon*. A new genus of uncertain systematic position. Kew Bull. No. 7, 310–13; 1911.

618. Durin, E. Contribution à l'étude des Moringées. Rev. gén. Bot. **25**, 449–71; 1913. *See* Just's Jber., Pt. 2, 1063; 1913.

619. Eames, A. J. On the origin of the broad ray in *Quercus*. Bot. Gaz. **49**, 161–7; 1910.

620. —— On the origin of the herbaceous type in the angiosperms. Ann. Bot. Lond. **25**, 214–24; 1911.

621. Ebes, K. *Vorming van Thyllen in Geveld Beukenhout*. Wageningen, pp. 56; 1937.

622. Edlin, H. L. A critical revision of certain taxonomic groups of the Malvales. New Phytol. **34**, 1–143; 1935.

623. Edman, G. Herba thymi serpylli och Herba thymi vulgaris. Farmacevtisk Revy, pp. 24; 1927. *See* Bot. Zbl., n.s. **13**, 125; 1928.

623a. Edmondson, C. H. Note on resistance of species of *Antedesma* to marine borers. Trop. Woods, **79**, 15; 1944.

624. Eggeling, W. J., and Harris, C. M. *Fifteen Uganda timbers*. Forest trees and timbers of the British Empire (Oxford), No. 4, pp. 114; 1939.

625. Elias, S. *Die Entwicklung der Sekretbehälter mit besonderer Berücksichtigung der Sekretbildung und Ausscheidung bei einzelnen Arten der Umbelliferen und Rutaceen*. Thesis, Berlin, pp. 64; 1929. *See* Just's Jber. 173; 1929 and Bot. Zbl., n.s. **19**, 68; 1931.

626. Elliott, J. H. The development of the vascular system in evergreen leaves more than one year old. Ann. Bot. Lond., n.s. **1**, 107–27; 1937.

627. Emould, M. Recherches anatomiques et physiologiques sur les racines respiratoires. Me. Acad. R. Belg. Cl. Sci. **2**, Ser. 6, pp. 52; 1921 (1922). *See* Just's Jber., Pt. 2, 87; 1921.

628. Engler, A. *Anacardiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 5; 1896.

629. —— Über die Verwerthung anatomischer Merkmale bei der systematischen Gliederung der Icacinaceae. S. B. Preuss. Akad. Wiss. 247–69; 1893.

630. —— *Icacinaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 5; 1896.

631. —— *Corynocarpaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii, Nachträge; 1897.

632. —— *Menispermaceae* in Engler's *Das Pflanzenreich*. iv. 94. 8–15; 1910.

633. —— *Poga oleosa* Pierre. Ein Öl liefernder Baum von Kamerun und Gabun. Notizbl. bot. Gart. Berl. **5**, 50. 294–8; 1913.

634. —— *Guttiferae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

635. —— *Podostemonaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 18a; 1930.

636. —— *Saxifragaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 18a; 1930.

637. —— *Brunelliaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 18a; 1930.

638. —— *Cunoniaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 18a; 1930.

639. —— *Zygophyllaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19a; 1931.

640. —— *Cneoraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19a; 1931.

641. —— *Rutaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19a; 1931.

642. —— *Simarubaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19a; 1931.

643. —— *Burseraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19a; 1931.

643a. Engler, A., and Gilg, E. *Syllabus der Pflanzenfamilien*. Berlin, pp. 420; 1924.

644. Engler, A., and Irmscher, E. *Saxifragaceae—Saxifraga* in Engler's *Das Pflanzenreich*, iv. 117. I–II; 1919.

645. Engler, A., and Krause, K. *Dichapetalaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19C; 1931.

646. —— *Loranthaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16B; 1935.

647. Engler, A., and Melchior, H. *Medusagynaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

648. Eriksson-Helsingfors, E. Über die Alkannawurzel und die Entstehung des Farbstoffes in derselben. Ber. dtsch. pharm. Ges. **20**, 202–8; 1910.

649. Esau, K. Ontogeny of phloem in the sugar beet (*Beta vulgaris* L.). Amer. J. Bot. **21**, 632–44; 1934.

650. —— Ontogeny and structure of collenchyma and of vascular tissues in celery petioles. Hilgardia, **10**, 431–65; 1936.

651. —— Vessel development in celery. Hilgardia, **10**, 479–84; 1936.

652. —— Ontogeny and structure of the phloem of tobacco. Hilgardia, **11**, 343–424; 1938.

653. —— The multinucleate condition in fibres of tobacco. Hilgardia, **11**, 427–31; 1938.

654. —— Developmental anatomy of the fleshy storage organ of *Daucus carota*. Hilgardia, **13**, 5. 175–209; 1940.

655. —— Phloem anatomy of tobacco affected with curly top and mosaic. Hilgardia, **13**, 8. 437–70; 1941.

—— Vascular differentiation in the vegetative shoot of Linum:

656. I. The procambium. Amer. J. Bot. **29**, 738–47; 1942.

657. II. The first phloem and xylem. Amer. J. Bot. **30**, 248–55; 1943.

658. —— Origin and development of primary vascular tissues in seed plants. Bot. Rev. **9**, 125–206; 1943.

659. —— Vascular differentiation in the pear root. Hilgardia, **15**, 3. 299–311; 1943.

660. —— Anatomical and cytological studies of beet mosaic. J. Agric. Res. **69**, 95–117; 1944.

661. —— Vascularization of the vegetative shoots of *Helianthus* and *Sambucus*. Amer. J. Bot. **32**, 18–29; 1945.

662. Esmans, F. Les Entandrophragma. Bull. agric. Congo belge, **24**, 222–35; 1933.

663. Étienne, R. *Étude anatomique de la famille des Epacridées*. Thesis, Toulouse, pp. 222; 1919.

664. —— *Contribution à l'étude structurale des Labiées endémiques des Îles Canaries*. Thesis, Paris, pp. 159; 1930.

665. Evenari, M. (Schwarz, W.). The physiological anatomy of the transpiratory organs and the conducting systems of certain plants typical of the wilderness of Judaea. J. linn. Soc. (Bot.), **51**, 389–407; 1938.

666. Ewald, E. Beiträge zur Kenntnis der sogenannten Schwimmhölzer. Flora, Jena, **114**, 394–400; 1921.

667. Ewert, H. *Die systematische Stellung der Gattung Hydrastis*. Thesis, Berlin, 1924. *See* Just's Jber., Pt. 2, 482; 1926.

668. Ewing, C. O., and Clevenger, J. F. *Ballota hirsuta* Benth., an adulterant of horehound (*Marrubium vulgare* L.). Amer. Pharm. Ass. **8**, 273–5; 1919.

669. Exbrayat-Durivaux, C. Notes sur la germination des Moringa Malgaches. Ann. Mus. colon. Marseilles, **38**, Ser. 4, 8, pp. 16; 1930.

670. Fanshawe, D. B. Studies of the trees of British Guiana. I. Crabwood (*Carapa guianensis*). Trop. Woods, **90**, 30–40; 1947.

671. Farenholtz, H. *Tropaeolaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19A; 1931.

672. Farr, W. K. Formation of microscopic cellulose particles in colourless plastids of cotton fibre. Contr. Boyce Thompson Inst. **12**, 181–94; 1941.

673. Faure, A. *Étude organographique, anatomique et pharmacologique de la famille des Cornacées* (*Groupe des Cornales*). Thesis, Lille, pp. 221; 1924.

674. Faust, E. C. F. Resin secretion in *Balzamorrhiza sagittata*. Bot. Gaz. **64**, 441–78; 1917.

675. Fedde, F. *Papaveraceae-Hypecoideae et Papaveraceae-Papaveroideae* in Engler's *Das Pflanzenreich*, iv. 104; 1909.

676. —— *Papaveraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 17B; 1936.

677. Federowicz, S. Die Drüsenformen der Rhinanthoideae-Rhinantheae. Bull. Inst. Acad. Sci. Cracovie Cl. m.n. B. 286–322; 1915. *See* Just's Jber., Pt. 1, 512; 1915.

678. Fegel, A. C. *Comparative anatomy and varying physical properties of trunk, branch and root wood in certain north eastern trees*. Tech. Publ. N.Y. St. Coll., No. 55, pp. 20; 1941.

679. Fehér, D. Über die Abscheidung von Harzbalsam auf den jungen Trieben unserer einheimischen *Populus*-Arten. Beih. bot. Zbl. **39**, 1. 81–103; 1922.

680. —— Anatomie der vegetativen Organe der Robinie. Erdész. Lap. **60**, 56–74; 1921 and **61**, 1–29; 1922. *See* Bot. Zbl., N.S. **2**, 132; 1922/3.

681. —— Anatomie der vegetativen Organe der *Robinia Pseudacacia* L. Teil. 3. Anatomie der Wurzel. Erdész. Lap. **63**, 83–100; 1924. *See* Bot. Zbl., N.S. **4**, 325; 1924/5.

682. Feinstein, B. S., and Slama, F. J. Differentiation of Belladonna, *Digitalis*, *Hyoscyamus*, and *Stramonium* leaves. J. Amer. pharm. Ass. **29**, 370; 1940. *See* Quart. J. Pharm. **13**, 358; 1940.

683. Fernandes, C. S. Da estrutura peculiarissima do cerne de *Schinopsis brasiliensis*. Arch. Inst. Pesquisas Agron. **3**, 141–7; 1941.

684. Fiebrig, C. La Flora del Jardín Botánico de la Trinidad-Asunción. Ensayo de un estudio ecológico sobre la flora Paraguaya. Rev. Jard. bot. Paraguay, **1**, 13–63; 1922.

685. Fiebrig-Gertz, C. Tropischer Waldbau. Die Tropenreihe, No. 42, 1931.

686. Fischer, F. *Beiträge zur Pharmakognosie der Plantaginalen und Rubialen. Anatomie des Laubblattes*. Thesis, Basel, pp. 82; 1937.

687. Flint, E. M. Structure of wood in blueberry and huckleberry. Bot. Gaz. **65**, 556–9; 1918.

688. Flury, F. Über die chemische Natur der Nesselgifte. Z. Ges. Exper. Med. **56**, 402–9; 1927. Bot. Zbl. **155**, 211; 1928.

689. Fohn, M. Zur Entstehung und Weiterbildung der Exkreträume von *Citrus medica* L. and *Eucalyptus globulus* Lab. Öst. bot. Z. **84**, 198–209; 1935.

690. Forsaith, C. C. Some features in the anatomy of the Malvales. Amer. J. Bot. **2**, 238–46; 1915.

691. —— Anatomical reduction in some Alpine plants. Ecology, **1**, 124–35; 1920.

Foster, A. S. Investigations on the morphology and comparative history of development of the foliar organs:

692. II. Cataphyll and foliage leaf form and organisation in the black hickory (*Carya buckleyi* var. *arkansana*). Amer. J. Bot. **18**, 864–87; 1931.

693. III. Cataphyll and foliage-leaf ontogeny in the black hickory (*Carya buckleyi* var. *arkansana*). Amer. J. Bot. **19**, 75–99; 1932.

694. —— Structure and development of sclereids in the petiole of *Camellia japonica* L. Bull. Torrey bot. Cl. **71**, 302–26; 1944.

695. —— Origin and development of sclereids in the foliage leaf of *Trochodendron aralioides* Sieb. et Zucc. Amer. J. Bot. **32**, 456–68; 1945.

696. —— The foliar sclereids of *Trochodendron aralioides* Sieb. et Zucc. J. Arnold Arbor. **26**, 155–62; 1945.

697. —— Comparative morphology of the foliar sclereids in the genus *Mouriria* Aubl. J. Arnold Arbor. **27**, 253–71; 1946.

698. Fourcroy, M. Sur une polystélie transitoire dans la racine de Carotte. Bull. Soc. bot. Fr. **89**, 237–9; 1942.

699. FOURCROY, M. Sur le présence de radicelles internes dans le tubercle du céleri. Bull. Soc. bot. Fr. **90,** 51–4; 1943.

700. —— Connections anormales des faisceaux dans la tige de *Bryonia dioica*. Bull. Soc. bot. Fr. **90,** 168–72; 1943.

701. —— Extinction progressive d'un faisceau caulaire de Bryone, demeuré libre de toute connection, dans le primitive entrenoed d'un rameau lateral. Bull. Soc. bot. Fr. **90,** 215–19; 1943.

702. FOURMENT, P., and MÉLIS, E. Contribution à l'étude anatomique de l'appareil sécréteur de quelques *Eucalyptus*. Bull. Soc. bot. Hist. nat. Afr. N. **23,** 25–7; 1932.

703. FOWERAKER, C. E. The mat-plants, cushion-plants and allied forms of the Cass river bed. Proc. N. Zealand Inst. **49,** 1–45; 1916.

704. FOXWORTHY, F. W. Philippine Dipterocarpaceae. Philipp. J. Sci. **6,** 231–87; 1911.

705. —— *Commercial woods of the Malay Peninsula*. Malayan For. Rec., No. 1, pp. 150; 1921.

706. FRANCIS, W. D. Some characteristics of Queensland rain-forests and rain-forest trees. Proc. roy. Soc. Qd. **34,** 209–19; 1922.

707. —— The development of buttresses in Queensland trees. Proc. roy. Soc. Qd. **36,** 21–37; 1924 (1925).

708. —— The development of the corrugated stems of some Eastern Australian trees. Proc. roy. Soc. Qd. **38,** 62–7; 1926 (1927).

709. FRANCKE, A. Zur Kenntnis der Exodermis der Asclepiadaceen. Planta, **3,** 1–26; 1927.

710. FRASER, L. An investigation of *Lobelia gibbosa* and *Lobelia dentata* I. Mycorrhiza, latex system and general biology. Proc. Linn. Soc. N.S.W. **56,** 497–525; 1931.

711. FREY-WYSSLING, A. Étude sur la relation existant entre le diamètre des tubes à latex et la production du caoutchouc dans l'*Hevea brasiliensis*. Bull. écon. Indochine, **34,** 341–74; 1931.

712. —— Zur Ontogenie des Xylems in Stengeln mit sekundären Dickenwachstum. Ber. dtsch. bot. Ges. **58,** 166–81; 1940.

713. FRIEDEL, J. Filiation des Papavéracées. Bull. Soc. bot. Fr. **74,** 673–88; 1927.

714. —— Quelques observations sur l'anatomie comparée du genre *Meconopsis* Viguier. Contribution à l'étude de la filiation Papavéracées. Bull. Soc. bot. Fr. **81,** 103–6; 1934.

[illegible] Anatomie comparée du *Pteridophyllum racemosum* Sieb. et Zucc. et de *Platystemon californicum* Benth. Bull. Soc. bot. Fr. **85,** 482–6; 1938.

716. —— Note sur la structure anatomique du *Pteridophyllum racemosum* Sieb. et Zucc. Bull. Soc. bot. Fr. **85,** 406–8; 1938.

717. —— 'Bois en V' chez le *Meconopsis Oliveriana* Franch. et Prain. Bull. Soc. bot. Fr. **86,** 274; 1939.

718. —— À propos d'une Solanée sans liber interne. Le '*Retzia capensis*' Thunb. Bull. Soc. bot. Fr. **86,** 428–30; 1939.

719. FRIEDEL, J., and YEN, T. P. Un curieux cas de convergence morphologique, une Caryophyllée à port d'Eryngium, le *Drypis spinosa* L. Comparison entre le *Drypis* et un *Eryngium*. Bull. Soc. bot. Fr. **72,** 416–22; 1925.

720. FRIESNER, G. M. Bacteria in the roots of *Gleditschia triacanthos*. Proc. Ind. Acad. Sci. **35,** 215–24; 1926.

721. FRISON, E. Notes sur la valeur économique des bois du *Corynanthe Paniculata* Welw. et du *Pausinystalia Bequaerti* De Willd. Bull. agric. Congo belge, **34,** 537–9; 1943.

722. FRITSCH, F. E. Recent discoveries of caoutchouc in plants. New Phytol. **2,** 25–30; 1903.

723. —— The use of anatomical characters for systematic purposes. New Phytol. **2,** 177–84; 1903.

724. FRITSCH, F. E. The anatomy of the Julianiaceae considered from the systematic point of view. Trans. Linn. Soc. Lond. Bot., Ser. 2, **7**, 129–51; 1908. *See* Just's Jber., Pt. 1, 435; 1908.

725. FRITSCHÉ, E. Recherches anatomiques sur la *Corydalis solida* Sm. Bull. Soc. bot. Belgique, **47**, 17–34; 1910. *See* Just's Jber., Pt. 2, 1603; 1910. Published also in Arch. Inst. bot. Univ. Liége, **5**, 1914.

726. —— Recherches anatomiques sur le *Taraxacum vulgare* Schrk. Arch. Inst. bot. Univ. Liége, **5**, pp. 25; 1914.

727. FROST, F. H. Bordered pits in parenchyma. Bull. Torrey bot. Cl. **56**, 259–63; 1930.

—— Specialization in secondary xylem of dicotyledons:

728. I. Origin of vessels. Bot. Gaz. **89**, 67–94; 1930.

729. II. The evolution of the end wall of the vessel segment. Bot. Gaz. **90**, 198–212; 1930.

730. III. Specialization of the lateral wall of the vessel segment. Bot. Gaz. **91**, 88–96; 1931.

731. FUCHS, L. *Folia* (*Herba*) *Plantaginis*. Pharmazeutische Presse. Wissenschaftlichpraktisches Heft, pp. 6; 1932.

732. FUJIOKA, M. More woods of Araliaceae with radial canals. Trop. Woods, **11**, 9; 1927.

733. FUNK, G. Beiträge zur Kenntnis der mechanischen Gewebesysteme in Stengel und Blatt der Umbelliferen. Beih. bot. Zbl. **29**, 1. 219–97; 1912.

734. FUNKE, G. L. On the biology and anatomy of some tropical leaf joints. Ann. Jard. bot. Buitenz. **40**, 45–74; 1929.

735. GALAMBOS, M. A hazai Thymelaeaceak szövettana (The histology of the Hungarian Thymelaeaceae). Bot. Közl. **16**, 69–99; 1917. *See* Bot. Zbl. **140**, 145; 1919.

736. GALLAGER, W. J. Contributions to the root anatomy of the Cupuliferae and Meliaceae. British Association Report, 749; 1906.

737. GAMBLE, J. S. *A manual of Indian timbers*. London, pp. 868; 1922.

738. GAMMERMAN, A. F., with NIKITIN, A. A., and NIKOLAEVA, T. L. *Opredelitel-'drevesin po mikroskopischeskim priznakam, s al'bomom mikrofotografy*. Leningrad, 1946.

739. GANDRUP, J. Ober den steencellenring in de schors van *Hevea*. Meded. Bes. Proefstat 19; 1921. *See* Just's Jber. 591; 1922.

740. —— Has *Hevea brasiliensis* in normal circumstances a compound cork layer? Meded. bes. Proefstat 1922. *See* Just's Jber. 591; 1922.

741. GANGSTAD, V. B. A morphological study of the leaf and tendril of *Passiflora coerulea*. Amer. Midl. Nat. **20**, 704–8; 1938.

742. GARD, M. Recherches sur les hybrides artificiels des Cistes obtenus par Ed. Bornet. Part II. Les espèces et les hybrides binaires. Beih. bot. Zbl. **29**, 2. 306–94; 1912.

743. GARRATT, G. A. Poisonous woods. J. For. **20**, 479–87; 1922.

744. —— *Some New Zealand woods*. Prof. Pap. N.Z. St. For. Serv., No. 1, pp. 50; 1924.

745. —— Philippine Dao (*Dracontomelum dao*). Trop. Woods, **27**, 1–11; 1931.

746. —— Systematic anatomy of the woods of the Myristicaceae. Trop. Woods, **35**, 6–48; 1933.

747. —— Bearing of wood anatomy on the relationships of the Myristicaceae. Trop. Woods, **36**, 20–44; 1933.

747A. —— Systematic anatomy of the woods of the Monimiaceae. Trop. Woods, **39**, 18–43; 1934.

748. —— The wood of *Symphonia globulifera*. Trop. Woods, **45**, 1–15; 1936.

749. GATES, F. C. A woody stem in *Gemella* induced by high warm water. Amer. J. Bot. **2**, 86–8; 1915.

750. Gates, R. R. An onagraceous stem without internodes. New Phytol. **11,** 50–3; 1912.

751. Gathercoal, E. N. The pharmacognosy of the medicinal Rhamnus barks. J. Amer. pharm. Assoc., pp. 39; 1915.

752. Gattiker, H. Vergleichende anatomisch-pharmakognostische Untersuchungen von Drogen der Gattungen *Antennaria*, *Gnaphalium* und *Helichrysum*. Ber. schweiz. bot. Ges. **49,** 5–122; 1939.

753. Gehrig, M. *Beiträge zur Pharmakognosie der Malvales. Anatomie des Laubblattes.* Thesis, Basel, pp. 84; 1938.

754. Geiger, F. Anatomische Untersuchungen über die Jahresringbildung von *Tectona grandis*. Jb. wiss. Bot. **55,** 521–607; 1915.

755. George, E. Senna leaflets—their palisade ratio values and ranges. Pharm. J., Ser. 4, **97,** 52; 1943.

756. George, L. Étude anatomique des tiges des Cytises de l'Afrique du Nord. Bull. Soc. bot. Hist. nat. Afr. N. **18,** 35–50; 1927. *See* Bull. Soc. bot. Fr. **74,** 1003; 1927.

757. Gérard, F. Étude systématique, morphologique et anatomique des Chlaenacées. Thesis, 1919. Published also in Ann. Mus. colon. Marseille, **27,** Sér. 3, 8, pp. 133; 1919.

758. Gérard, G. *Recherches sur les bois des différentes espèces des Légumineuses africaines.* Univ. Paris, École Supérieure de Pharmacie, No. 10; 1907.

759. Gerry, E. Tyloses; their occurrence and practical significance in some American woods. J. Agric. Res. **1,** 445–69; 1914.

760. —— Fibre measurement studies; length variations, where they occur and their relation to the strength and uses of wood. Science, **41,** 179; 1915.

761. Gerry, E., and Scheffer, T. C. Color tests for differentiation of heartwood and sapwood of certain oaks and pines. U.S. For. Prod. Lab. Tech. Note, No. 253, pp. 2; 1945.

762. Ghosh, E. On the microstructure of the stem of Bengal Cucurbitaceae with reference to its value in taxonomy. J. Indian bot. Soc. **11,** 259–70; 1932.

763. Ghosh, S. S. *How to identify timbers. IV. Timbers for boxes and packing cases.* Ind. For. Leaflet No. 46, 30–59; 1943.

764. Giersch, S. C. The anatomy of *Ranunculus asiaticus* L. var. *superbissimus* Hort. Amer. Midl. Nat. **15,** 343–57; 1934.

765. Gilbert, S. G. Evolutionary significance of ring porosity in woody angiosperms. Bot. Gaz. **102,** 1. 105–20; 1940.

766. Gilg, E. *Thymelaeaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 6a; 1894.

767. —— *Vitaceae* (*Ampelidaceae*) in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 5; 1896.

768. —— Zur Frage der Verwandschaft der Salicaceae mit den Flacourtiaceae. Bot. Jb. Festband, **50,** 424–34; 1914. *See* Just's Jber., Pt. 1, 872; 1914.

769. —— *Eucryphiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

770. —— *Ochnaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

771. —— *Dipterocarpaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

772. —— *Canellaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

773. —— *Flacourtiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

774. —— *Stachyuraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

775. —— *Turneraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

776. Gilg, E. *Loasaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

777. —— *Datiscaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

778. —— *Ancistrocladaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

779. Gilg, E., Brandt, W., and Schürhoff, P. N. *Lehrbuch der Pharmakognosie.* Berlin, pp. 530; 1927.

780. Gilg, E., and Schuster, J. Zur Geschichte und Kenntnis der Sennesblätter-Verfälschung mit *Cassia auriculata* L. Angew. Bot. **2,** 1–8; 1920.

781. Gilg, E., and Werdermann, E. *Dilleniaceae* in Engler and Prantl's *Die natürl. Pflanzenfam*, Auf. 2, 21; 1925.

782. —— *Actinidiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

783. —— *Marcgraviaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

784. Gilly, C. L. Studies in the Sapotaceae. II. The Sapodilla-Nispero Complex. Trop. Woods, **73,** 1–22; 1943.

785. Gin, A. Recherches sur les Lythracées. Trav. Lab. Mat. méd. Paris, **6,** pp. 166; 1909.

786. Giordano, G. Cenni monografici sulle piante forestale e sui legnami dell' A.O.I. Riv. for. ital. **1,** 183–8, 238–44, 447–54, 554–60, 597–606; 1939 and **2,** 32–6, 96–104; 1940.

787. —— Nuova piante forestale dell' A.O.I. Riv. for. ital. **2,** 250–8; 1940.

788. Glabisz, J. Morphologische und physiologische Untersuchungen an *Ceropegia Woodii* Schlechter. Beih. bot. Zbl. **23,** 1. 65–136; 1908.

788a. Gleason, H. A., and Panshin, A. J. *Swietenia Krukovii*; a new species of mahogany from Brazil. Amer. J. Bot. **23,** 21–5; 1936.

789. Gleichgewicht, E. La structure anatomique des organes végétatifs chez le *Chaenomeles japonica* Ldl. (*Cydonia japonica* P.) *rubra*, *rosiflora*, et le *Cydonia vulgaris* P. Kosmos, Lwów, **47,** 361–70; 1922.

790. Gleisberg, W. Vergleichend-anatomische Untersuchung des Blattes der *Vaccinium oxycoccus* Typen. Ber. dtsch. bot. Ges. **40,** 139–47; 1922.

791. —— Systematisch-kritische Vorarbeit für eine Monographie der species *Vaccinium oxycoccus* L. Bot. Arch. **2,** 1–34; 1922.

792. Gonggrijp, J. W. Rosenhout, bois de rose femelle, uit Suriname. Ind. Mercuur, No. 43, 269; 1920.

793. —— Microscopische structuur van hout in verband met bestandheid tegen paalworm. Ind. Mercuur, No. 25; 1921.

794. —— *Gegerens betreffende een onderzoek Nederlandsch-Indische Houtsoorten, welke tegen den paalworm bestand zijn.* Meded. Proefst. Boschw. Batavia, No. 25, pp. 147; 1932.

795. Goodlatte, A. R. Notes on the anatomy of *Parosela spinosa* (A. Gray) Heller. Bull. Torrey bot. Cl. **36,** 573–82; 1909.

796. Gore, U. R., and Taubenhaus, J. J. Anatomy of normal and acid injured cotton roots. Bot. Gaz. **92,** 4. 436–41; 1931.

797. Goris, A. *Ranunculus thora* Linn. Contribution à l'étude botanique, chemique et physiologique. Trav. Lab. Mat. méd. Paris, **30,** pp. 149; 1939.

798. Goris, M. A. Contribution à l'étude des Anacardiacées de la tribu des Mangiférées. Ann. Sci. nat. b., Ser. 9, **11,** 1–29; 1910. *See* Just's Jber., Pt. **2,** 1586; 1910.

799. Gouwentak, C. A. Macroscopical and anatomical characters of the wood of *Eucalyptus globulus* Labill. and *E. rostrata* Schl. Meded. Landb. Hoogesch. **39,** 3–17; 1935.

800. Graefe, E. Das leichteste Holz. Umschau, **38,** 170–1; 1934.

801. Gráf, L. Die Entwicklung des Leitungssystems im Stengel von *Bidens tripartitus* (L.). Flora, Jena, **32,** 151–73; 1938.

802. Graf, W. Beiträge zur Kenntnis der Gattung *Populus*. Beih. bot. Zbl. **38,** I. 405–54; 1921.

803. Gravis, A. Contribution à l'anatomie des Amarantacées. Arch. Inst. bot. Univ. Liége, **4,** 1–65; 1907.

804. —— Observations anatomiques et éthologiques sur le *Genista radiata* Scop. Bull. Soc. Roy. Bot. Belg. **62,** 110–18; 1929.

805. —— Contribution à l'étude des variations. Nanisme et pédocarpisme du *Plantago coronopus* L. Rec. quelques trav. d'anatomie exécutés à Liége de 1929–35. Brussels, 1936.

806. —— Observations anatomiques et éthologiques sur les Cactées. Rec. quelques trav. d'anatomie exécutés à Liége de 1929–35. Brussels, 1936.

807. Gray, R. G. Cork formation in *Veronica Lyallii*. Trans. bot. Soc. Edinb. **32,** 362–7; 1937.

808. Green, M. H., and Buck, W. S. The stereids in the petioles of *Nymphea advena*. Proc. Pa. Acad. Sci. **11,** 20–2; 1937. *See* Biol. Abstr. **12,** No. 10595; 1938.

809. Greene, E. C., Jun. Santa Maria: a neotropical timber of the genus *Calophyllum*. Trop. Woods, **30,** 9–16; 1932.

810. Greenfield, M. Histology of *Salsola kali* L. var. *tenuifolia* G. F. W. May. Kansas Univ. Sci. Bull. **7,** 263–73; 1913.

Greenish, H., and Wallis, T. E. Practical Pharmacognosy:

811. III. Pharm. J., Ser. IV, **56,** 289–91; 1923.

812. V. Pharm. J., Ser. IV, **58,** 659; 1924.

813. Greenman, J. M. Genera from the standpoint of morphology. Bull. Torrey bot. Cl. **67,** 371–4; 1940.

814. Gregor, J. W. The units of experimental taxonomy. Chron. Bot. **7,** 193–6; 1942.

815. Gregory, C. T. The taxonomic value and structure of peach leaf glands. Cornell Univ. Agric. Exptl. Stat. Bull. **365,** 183–22; 1915. *See* Just's Jber. 764; 1916.

816. Greiss, E. A. M. Effect of water supply on the structure of the xylem elements in certain trees in Egypt. Bull. Inst. égypt. **20,** 193–224; 1939.

817. —— On the rate of water conduction in the wood of certain trees in Egypt. Bull. Fac. Sci. Fouad I Univ. Cairo, **25,** 35–54; 1945.

818. Greshoff, M. Phytochemical investigations at Kew. Kew Bull. No. 10, 397–418; 1909.

819. Grevel, W. Anatomische Untersuchungen über die Familie der Diapensiaceae. Bot. Zbl. **69,** 309–15; 1897.

820. Griebel, C. Die Zellelemente des Maniokmehles. Z. Untersuch. Nahr.- u. Genussm. **43,** 168–71; 1922. *See* Just's Jber. 624; 1922.

821. Griffioen, K. A study of the dark coloured duramen of ebony. Rec. Trav. bot. néerland. **31,** 780–809; 1934.

822. Griffiths, C. O. The structure of pomegranate rind. Quart. J. Pharm. **8,** 622–30; 1935.

823. Groom, P. The evolution of the annual ring and medullary rays of *Quercus*. Ann. Bot. Lond. **25,** 985–1003; 1911.

824. —— The medullary rays of Fagaceae. Ann. Bot. Lond. **26,** 1124–5; 1912.

825. —— Report on the American oak wood used in the construction of beer casks. J. Inst. Brew. **28,** 647–77; 1922.

826. —— Excretory systems in the secondary xylem of Meliaceae. Ann. Bot. Lond. **40,** 631–49; 1926.

827. Groom, P., and Wilson, S. E. On the pneumatophores of paludal species of *Amoora*, *Carapa*, and *Heritiera*. Ann. Bot. Lond. **39,** 9–24; 1925.

828. Gross, H. Beiträge zur Kenntnis der Polygonaceen. Bot. Jb. **49,** 234–339; 1912.

829. Gruning, G. *Euphorbiaceae-Porantheroideae et Ricinocarpoideae* in Engler's *Das Pflanzenreich*, iv. 147; 1913.

830. GRÜSS, J. Die Luftblätter der Nymphaeaceen. Ber. dtsch. bot. Ges. **45**, 454–8; 1927.

831. —— Die Haustoren der Nymphaeaceen. Ber. dtsch. bot. Ges. **45**, 459–66; 1927.

832. GUENOT, J. F. *Contributions à l'étude anatomique des Pittosporacées.* Thesis, Paris, pp. 78; 1906.

833. GUÉRIN, P. Cellules à mucilage chez les Urticées. Bull. Soc. bot. Fr. **57**, 399–406; 1910.

834. —— L'*Urera Humboltii* H. Baill. et ses affinités. C. R. Acad. Sci. Paris, **168**, 517–19; 1919.

835. —— Le mucilage chez les Urticées. C. R. Acad. Sci. Paris, **174**, 480–2; 1922.

836. —— Les Urticées: cellules à mucilage, laticifères et canaux sécréteurs. Bull. Soc. bot. Fr. **70**, 125–36, 207–15, 255–63; 1923.

837. —— Le genre *Bifora*; étude anatomique du *Bifora radians* Bieb. Bull. Soc. bot. Fr. **70**, 481–7; 1923.

838. GUILLAUMIN, A. Recherches sur le genre *Pachylobus.* J. Bot., Sér. II, **2**, 1–19; 1909.

839. —— *Recherches sur la structure et le developpement des Burseracées. Application à la systématique.* Thesis, Paris, pp. 100; 1910. Published also in Ann. Sci. nat. b., Sér. 9, **10**, 1909–10.

840. —— Observations sur quelques plantes critiques de la region indo-malaise rapportées aux Burseracées. Ann. Jard. bot. Buitenz. **26**, Sér. 2, xi. 210–17; 1912.

841. —— Qu'est-ce que l'*Aralia lizei*? J. Soc. nat. hort. Fr., Sér. 4, **24**, 522–5; 1923.

842. —— Recherches sur l'anatomie et la classification des Balanopsidacées. Rev. gén. Bot. **37**, 443–9; 1925.

843. —— Observations morphologiques et anatomiques sur le genre *Oncotheca.* Rev. gén. Bot. **50**, 629–35; 1938.

844. GUIR, L. J., and BURRESS, R. M. Anatomy of *Taraxacum officinale* 'Weber'. Trans. Kans. Acad. Sci. **45**, 94–7; 1942. *See* Biol. Abstr. **17**, No. 14374; 1943.

845. GUNDERSEN, A. L. *Recherches anatomiques sur les Caprifoliacées.* Thesis, Paris, pp. 79; 1910.

846. —— The classification of the dicotyledons. Torreya, **39**, 108–11; 1939.

847. GUPTA, K. M. On the wood anatomy and theoretical significance of homoxylous angiosperms. J. Indian bot. Soc. **13**, 71–101; 1934.

848. —— A review of the genus *Dipterocarpoxylon* of Holden, with description of a new species of *D. Holdeni.* from the Irrawady. Proc. Indian Acad. Sci. **1**, 633–9; 1935.

849. —— Critical remarks on *Dipterocarpoxylon burmense* Holden: *Irrawadioxylon* gen. nov. Proc. Indian Acad. Sci. **1**, 549–55; 1935.

850. GUNNERY, H. Yield production in *Hevea*—a study of sieve-tube structure in relation to latex yield. J. Rubb. Res. Inst. Malaya, **6**, 1–12; 1935.

851. GÜRKE, M. *Melianthaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 5; 1896.

852. GUTTENBERG, H. VON. Die Harzdrüsen von *Lysimachia vulgaris* L. Planta, **5**, 232–8; 1928.

853. GWYNNE-VAUGHAN, D. T. On some points in the morphology and anatomy of the Nymphaeaceae. Trans. Linn. Soc. Lond. Bot. **5**, 287–99; 1897.

854. GYHR, M. H. *Beiträge zur Anatomie des Laubblattes pharmazeutisch-gebräuchlicher Rosaceendrogen.* Thesis, Basel, 1–86; 1930.

855. GYR, F. *Pharmakognostiche Untersuchungen über einige als Arzneidrogen verwendete Sedum-Arten.* Thesis, Zürich, pp. 61; 1940.

856. HAAR, A. W. VAN DER. Beitrag zur Anatomie der Araliaceae. Die Blätter und Stengel von *Aralia montana* Bl. Rec. Trav. bot. néerland. **19**, 277–80; 1922.

857. Haberlandt, G. *Physiological plant anatomy.* English translation by M. Drummond, London, pp. 777; 1914.

858. —— Über den Blattbau der Crataegomespili von Bronvaux und ihrer Eltern. S. B. preuss. Akad. Wiss. Phys.-Math. Kl. **17,** 170–208; 1926.

859. —— Über die Sonnen- und Schattenblätter der Crataegomespili und ihrer Eltern. S. B. preuss. Akad. Wiss. Phys.-Math. Kl. **20,** 3–14; 1934.

860. —— Blattepidermis und Palisadengewebe der Crataegomespili und ihrer Eltern. S. B. preuss. Akad. Wiss. Phys.-Math. Kl. **12,** 1–15; 1934.

861. —— Über den Blattbau sexueller Bastarde zwischen Mispel und Weissdorn. S. B. preuss. Akad. Wiss. Phys.-Math. Kl. **6,** 1–26; 1935.

862. Haehnel, K. *Anatomisch-biologische Betrachtungen über die Kakteen.* Deutsch. Schule zu Mexico, pp. 30; 1912.

863. Hagerup, O. The structure and biology of Arctic flowering plants, II. 10. Caprifoliaceae. Meddel. öm. Grönland **37,** 151–64; 1915. *See* Just's Jber., Pt. 1, 239; 1920.

864. —— En hygrofil Bailgplante (*Aeschynomene aspera* L.) med Bakteriknolde paa staingelen. Dansk. bot. Archiv. **5,** 14. 1–9; 1928.

865. —— Vergleichende morphologische und systematische Studien über die Ranken und andere vegetative Organe der Cucurbitaceen und Passifloraceen. Dansk. bot. Archiv. **6,** 8. 1–104; 1930.

866. —— Über die Bedeutung der Schirmform der Krone von *Acacia seyal* Del. Dansk. bot. Archiv. **6,** 4. 1–20; 1930.

867. —— Zur Abstammung einiger Angiospermen durch Gnetales und Coniferae. K. danske vidensk. Selsk. Skr. **11,** 4. 1934.

868. Hahmann, C. Beiträge zur anatomischen Kenntnis der *Brunfelsia hopeana* Benth., im besonderen deren Wurzel, Radix Manaca. Angew. Bot. **2,** 113–33 and 179–91; 1920.

869. Hale, J. D. The trabeculae of Sanio in angiosperms. Science, **57,** 718; 1923.

870. —— *The identification of woods commonly used in Canada.* Bull. For. Br. Can., No. 81, pp. 48; 1932.

871. Halket, A. C. The morphology of *Salicornia*—an abnormal plant. Ann. Bot. Lond. **42,** 525–30; 1928.

872. Hall, M. M., and Goodspeed, T. H. Chrysil, a new rubber from *Chrysothamnus nauseosus.* Univ. Calif. Publ. Bot. **7,** 159–78, 183–264, 265–78; 1919. *See* Just's Jber. 593; 1922.

873. Hall, W. Storage tracheids of the stem of *Villarsia.* Aust. Nat. **5,** 84; 1923.

874. Hallier, H. On the origin of angiosperms. Bot. Gaz. **45,** 196–8; 1908.

875. Hamet, R. Sur le développement des formations médullaires des *Granovia.* Ann. Sci. nat. b., Sér. 9, **15,** 253–56; 1912.

876. —— Sur les formations libéro-ligneuses anormales de la tige des *Granovia.* C. R. Acad. Sci. Paris, **154,** 604–6; 1912.

877. —— Sur les formations cribro-vasculaires médullaires de deux Crassulaceae. C. R. Acad. Sci. Paris, **180,** 1424–6; 1925.

878. —— Sur un type de formation cribro-vasculaires médullaires nouveau pour la famille des Crassulacées. C. R. Acad. Sci. Paris, **181,** 1163–4; 1925.

879. Hamilton, A. G. The xerophilous characters of *Hakea dactyloides* Cav. Proc. Linn. Soc. N.S.W. **39,** 152–6; 1914.

880. Hanausek, T. F. Untersuchungen über die kohleähnliche Masse der Kompositen. Denkschr. Akad. Wiss. Wien Math.-Naturw. Kl. **87,** 93–142; 1912. *See* Just's Jber., Pt. 2, 1045; 1911.

881. —— Bemerkung zu dem Aufsatz von Ernst-Kratzmann. Über den Bau und die vermutliche Funktion der Zwischenwanddrüsen von *Rhododendron* u. a. Öst. bot. Z. **61,** 21–2; 1911.

882. —— Über ein neues Vorkommen der 'Inklusen' in dem Blatte von *Pistacia lentiscus* Linn. nebst Bemerkungen über den anatomischen Bau dieses Blattes. Ber. dtsch. bot. Ges. **32,** 117–22; 1914.

882A. Handa, T. Über die sukzessiven Holzbastringe von *Pueraria triloba* Makino und *Wistaria floribunda* DC. Bot. Mag. Tokyo, **46,** 13–22; 1932.

883. —— Abnormal vascular bundle in the stem of *Campsis grandiflora* K. Schum. Jap. J. Bot. **8,** 47–57; 1936.

884. —— Anatomical observations on the internal cambium of the stem in *Marsdenia tomentosa* Merr. et Decne. Jap. J. Bot. **8,** 59–64; 1936.

885. —— Anomalous secondary growth in *Bauhinia japonica* Maxim. Jap. J. Bot. **9,** 37–53; 1937.

886. —— Anomalous secondary growth in the axis of *Bauhinia championi* Benth. Jap. J. Bot. **9,** 3. 303–11; 1937.

887. Handley, W. R. C. Some observations on the problem of vessel length determination in woody dicotyledons. New Phytol. **35,** 457–71; 1936.

888. Hanson, H. C., and Brenke, B. Seasonal development of growth layers in *Fraxinus campestris* and *Acer saccharinum.* Bot. Gaz. **82,** 286–305; 1926.

889. Hardy, A. D. The distribution of leaf glands in some Victorian Acacias. Vict. Nat. **29,** 26–32; 1912. *See* Just's Jber., Pt. 2, 823; 1912.

890. Hare, C. L. The arborescent senecios of Kilimanjaro: a study in ecological anatomy. Trans. roy. Soc. Edinb. **60,** 355–71; 1940.

891. Harlow, W. M. *The chemical nature of the middle lamella.* Tech. Publ. N.Y. St. Coll. For., No. 30, pp. 7; 1930.

892. Harms, H. Einige Nutzhölzer Kameruns. II. Leguminosae. Notizbl. bot. Gart. Berl. **21,** 9–75; 1913. *See* Just's Jber., Pt. 2, 1071; 1913.

893. —— *Malesherbiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

894. —— *Passifloraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

895. —— *Achariaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

896. —— *Caricaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

897. —— *Hammamelidaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 18A; 1930.

898. —— *Eucommiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 18A; 1930.

899. —— *Grubbiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16B; 1935.

900. —— *Rafflesiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16B; 1935.

901. —— *Hydnoraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16B; 1935.

902. —— *Balanophoraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16B; 1935.

903. —— *Nepenthaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 17B; 1936.

904. —— *Meliaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19*b* I; 1940.

905. —— *Akaniaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19*b* I; 1940.

906. Harrar, E. S. Notes on the genus *Flindersia* R.Br. and the systematic anatomy of the important flindersian timbers indigenous to Queensland. J. Elisha Mitchell Sci. Soc. **53,** 24–6; 1937.

907. —— Notes on starch grains in septate fibre-tracheids. Trop. Woods, **85,** 1–9; 1946.

908. Harris, C. M. Stone in *Chlorophora excelsa* B. & H. Emp. For. J. **12,** 229–38; 1933.

909. HARSHBERGER, J. W. The comparative leaf structure of the sand dune plants of Bermuda. Proc. Amer. phil. Soc. **47,** 97–110; 1908.

910. HART, F. The histology of Vilca bark. J. Amer. pharm. Ass. **11,** 906–9; 1922.

911. —— A microscopical comparison of some official herbs and their substitutes. J. Amer. pharm. Ass. **12,** 489–91; 1923.

912. HARVEY-GIBSON, R. J. The physiological properties of West African boxwood. Bio-chem. J. **1,** 39–53; 1906.

913. —— Note on the synonymy and histological characters of East London boxwood (*Gonioma kamassi* E. Mey.). Bio-chem. J. **6,** 127–9; 1911.

914. —— Observations on the morphology and anatomy of the genus *Mystropetalon* Harv. Trans. Linn. Soc. Lond. Bot., Ser. 2, **8,** 143–54; 1913.

HARVEY-GIBSON, R. J., *et al.*

(and BRADLEY, M.). Contribution towards a knowledge of the anatomy of the lower dicotyledons:

915. I. The anatomy of the stem of the Papaveraceae. Trans. roy. Soc. Edinb. **51,** 589–608; 1917.

(and HORSEMAN, E.)

916. II. Anatomy of the stem of the Berberidaceae. Trans. roy. Soc. Edinb. **52,** 501–15; 1919.

917. HASLER, O. Entwicklungsgeschichte und vergleichende Anatomie der pharmakognostisch wichtigen Rhamnusrinden unter besonderer Berücksichtigung der Calcium-oxalate Bildung. Ber. schweiz. bot. Ges. **45,** 519–93; 1935.

918. HASSELBERG, G. B. E. The vascular system in the stem-axis of the genus *Fagraea*. Svensk. bot. Tidskr. **25,** 229–37; 1931.

919. HATE, V. M. A note on the structure of the giant creeper *Calycopteris floribunda*. J. Bombay nat. Hist. Soc. **20,** 837–40; 1911.

920. HAUMAN, L. *Les Lobelia géants des montagnes du Congo Belge*. Brussels, pp. 52; 1933.

921. HAURI, H. *Anabasis aretioides* Moq. et Coss. eine Polsterpflanze der algerischen Sahara. Beih. bot. Zbl. **28,** 1. 323–420; 1912.

922. HAVIS, L. Anatomy of the hypocotyl and roots of *Daucus carota*. J. Agric. Res. **58,** 557–64; 1939.

923. HAYATA, B., and SATAKE, Y. Contributions to the systematic anatomy of some Japanese plants. Bot. Mag. Tokyo, **43,** 73–106; 1929. Bull. Soc. bot. Fr. **76,** 826; 1929.

924. HAYDEN, A. The ecologic foliar anatomy of some plants of a prairie province in Central Iowa. Amer. J. Bot. **6,** 69–85; 1919.

925. —— The ecological subterranean anatomy of some plants of a prairie province in Central Iowa. Amer. J. Bot. **6,** 87–104; 1919.

926. HAYEK, A. V. Die Trichome einiger heimischer Senecio-Arten. Öst. bot. Z. **55,** 292–7; 1915.

927. HAYWARD, H. E. *The Structure of Economic Plants*. New York, pp. 674; 1938.

928. HECKEL, E. Sur la nature résineuse rapprochée des écorces de *Sarcocaulon* du Cap et de quelques Kalanchoë de Madagascar. C. R. Acad. Sci. Paris, **148,** 1073–5; 1909.

929. HECTOR, J. M. *Introduction to the botany of field crops*. Vol. II. Non-cereals. Johannesburg, S. Africa, 1936.

930. HEDGCOCK, G. Parasitism in *Comandra umbellata*. J. Agric. Res. **5,** 133–5; 1915.

931. HÉDIN, L. Commercial mahoganies of French Cameroon. Trop. Woods, **21,** 1–5; 1930.

931A. HEIDEN, H. Anatomische Characteristik der Combretaceen. Bot. Zbl. **55,** 353–60, 385–91; **56,** 1–12, 65–75, 129–37, 163–70, 193–200, 221–30; 1893.

932. HEILBRONN, M. Die Spaltöffnungen von *Camellia japonica* L. (*Thea japonica* Nois.). Bau und Funktion. Ber. dtsch. bot. Ges. **34,** 22–31; 1916.

933. HEIMERL, A. *Nyctaginaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16c; 1934.

934. —— *Phytolaccaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16c; 1934.

935. —— *Gyrostemonaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16c; 1934.

936. —— *Achatocarpaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16c; 1934.

937. HEIMSCH, C., Jun. Wood anatomy and pollen morphology of *Rhus* and allied genera. J. Arnold Arbor. **21**, 279–91; 1940.

938. —— Comparative anatomy of the secondary xylem of the 'Gruinales' and 'Terebinthales' of Wettstein with reference to taxonomic groupings. Lilloa, **8**, 83–198; 1942. *See* Trop. Woods, **71**, 39; 1942.

939. HEIMSCH, C., Jun., and WETMORE, R. H. The significance of wood anatomy in the taxonomy of the Juglandaceae. Amer. J. Bot. **26**, 8. 651–60; 1939.

940. HEINRICHER, E. Die Eiweisslauche der Cruciferen und verwandte Elemente in der Rhoeadinenreihe. Mitt. bot. Inst. Graz. i. 1–92; 1886.

941. —— Ph. van Tieghem's Anschauungen über den Bau der *Balanophora* Knolle. S. B. Akad. Wiss. Wien, **1**, 337–46; 1908. *See* Just's Jber., Pt. 1, 462; 1908.

942. —— Über Versuche, die Mistel (*Viscum album* L.) auf monocotylen und auf sukkulenten Gewächshauspflanzen zu ziehen. S. B. Akad. Wiss. Wien, **12**, 541–72; 1912. *See* Just's Jber., Pt. 2, 804; 1912.

943. —— Das Absorptionssystem der Wacholdermistel (*Arceuthobium oxycedri* (DC.) M.B.) mit besonderer Berücksichtigung seiner Entwicklung und Leistung. S. B. Akad. Wiss. Wien, Math.-Naturw. Kl. **132**, 143–94; 1923. *See* Just's Jber., Pt. 1, 689; 1923.

944. —— Über die Anschlussverhältnisse der Loranthoideae an die Wirte und die verschiedenartigen Wucherungen (Rosenbildungen) die dabei gebildet waren. Bot. Arch. **15**, 299–325; 1926.

945. HEITZMAN, W. Ein Beitrag zur Kenntnis der anatomischen Verhältnisse im Bau von *Cyclamen persicum* Mill. Bull. Ac. Pol. Sci. et Lettr. Cl. Sc. Mat. Nat., Ser. B, 69–73; 1924. *See* Just's Jber. 320; 1924.

946. HELM, J. Anlage und Entwicklung der Blattstieldornen von *Quisqualis indica*. Flora, Jena, N.S. **31**, 425–37; 1937.

947. HEMENWAY, A. F. Studies in the phloem of the dicotyledons. I. Phloem of the Juglandaceae. Bot. Gaz. **51**, 131–5; 1911.

948. HEMENWAY, A. F., and BREAZEALE, L. A study of *Neomammilaria Macdougali* (Rose). Amer. J. Bot. **22**, 493–9; 1935.

949. HEMSLEY, W. B. On the genus *Corynocarpus* Forst. with descriptions of two new species. Ann. Bot. Lond. **17**, 743–60; 1903.

950. —— On the genus *Corynocarpus* Forst. Supplementary note. Ann. Bot. Lond. **18**, 179–80; 1904.

951. —— On the Julianiaceae: a new natural order of plants. Trans. roy. Soc. Lond. B, **199**, 169–97; 1907.

952. HENDERSON, E. M. The stem structure of *Sargentodoxa cuneata* Rehd. et Wils. Trans. bot. Soc. Edinb. **29**, 57–62; 1927.

953. HENDERSON, M. W. A comparative study of the structure and saprophytism of the Pyrolaceae and Monotropaceae with reference to their derivation from the Ericaceae. Contr. bot. Lab. Univ. Pa. **5**, 42–109; 1919.

954. HEPPELER, F. *Beiträge zur Kenntnis der Gattung Rhamnus mit besonderer Berücksichtigung des Emodinvorkommens.* Thesis, Berlin; 1924. *See* Just's Jber., Pt. 2, 488; 1926.

955. HERBERT, D. A. The root parasitism of western Australian Santalaceae. J. roy. Soc. W. Aust. **11**, 127–49; 1925.

956. HERMANN, H. Vergleichende Holzanatomie der Pappeln und Baumweiden. Bot. Arch. **2**, 35–56 and 79–112; 1922.

957. Hess, K. Über neue Ergebnisse im Aufbau der pflanzlichen Zellwand. Angew. Chem. **52,** 284; 1939. *See* Biol. Abstr. **15,** No. 24176; 1941.

958. Hess, R. Vergleichende Untersuchungen über die Zwillingshaare der Compositen. Bot. Jb. **68,** 435–96; 1938.

959. Hess, R. W. Occurrence of rhaphides in wood. Trop. Woods, **46,** 22–31; 1936.

960. —— Queries for taxonomists. Trop. Woods, **84,** 24–5; 1945.

—— Identification of New World timbers:

961. I. Trop. Woods, **86,** 14–25; 1946.

962. II. Trop. Woods, **87,** 11–19; and **88,** 12–13; 1946.

963. III. Trop. Woods, **88,** 13–30; 1946.

—— Keys to American woods. For I–XVI see Nos. **1864–78.**

964. XVII. Woods with vasicentric tracheids.

965. XVIII. Fibres with spiral thickenings.

966. XIX. Special fibres in parenchyma-like arrangement.

967. XX. Woods with unilaterally paratracheal parenchyma. Trop. Woods, **85,** 11–19; 1946.

968. Hiesey, W. M. Environmental influence and transplant experiments. Bot. Rev. **6,** 181–203; 1940.

969. Hill, A. W. The production of hairs on the stems and petioles of *Tropaeolum peregrinum.* Ann. Bot. Lond. **26,** 589–92; 1912.

970. —— Present day problems in taxonomic and economic botany. Presidential address to Section K, Brit. Assoc. for Advancement of Sci., Bristol, pp. 29; 1930.

971. —— A hybrid Daphne (*D. petraea* Leybold and *D. cneorum* L.). Ann. Bot. Lond. **45,** 229–31; 1931.

972. —— The monocotylous seedlings of certain dicotyledons with special reference to the Gesneriaceae. Ann. Bot. Lond., N.S. **2,** 5. 127–44; 1938.

973. Hill, T. G. On the anatomy of the stem of *Dalbergia paniculata* Roxb. Ann. Bot. Lond. **15,** 1–3; 1901.

974. —— Stelar theories. Sci. Progress, No. 2, 1–18; 1906.

975. Himmel, W. J. A contribution to the biophysics of some *Podophyllum* petioles. Bull. Torrey bot. Cl. **54,** 419–549; 1927.

976. Himmelbaur, W. Die Berberidaceen und ihre Stellung im System. Denkschr. Akad. Wiss. Wien, **89,** 733–96; 1913. *See* Just's Jber., Pt. 2, 1073; 1913.

977. Hinchliff, M., and Priestley, J. H. The physiological anatomy of the vascular plants characteristic of peat. Naturalist, Lond. 263–8; 1922.

978. —— Further notes upon the vascular plants characteristic of peat. Naturalist, Lond. 201–9; 1924.

979. Hirano, E. Relative abundance of stomata in *Citrus* and some related genera. Bot. Gaz. **92,** 3. 296–310; 1931.

980. Hoar, C. S. A comparison of the stem anatomy of the Cohort Umbelliflorae. Ann. Bot. Lond. **29,** 55–63; 1915.

981. —— The anatomy and phylogenetic position of the Betulaceae. Amer. J. Bot. **3,** 415–35; 1916.

982. Hochreutiner, B. P. G. La parenté des Guttifères et des Hypéricenées. C. R. Soc. Phys. Hist. nat. Genève, **36,** 26–7; 1919.

983. Hoeck, A. V. The anatomy of *Megalodonta beckii.* Amer. Midl. Nat. **3,** 336–42; 1914.

984. Hoffstadt, R. E. The vascular anatomy of *Piper methysticum.* Bot. Gaz. **62,** 115–32; 1916.

985. Hogstad, A. A morphological and chemical study of *Nicandra physaloides* (L.) Pers. J. Amer. pharm. Ass. **12,** 576–82; 1923. *See* Just's Jber., Pt. 1, 708; 1923.

986. Holden, R. Reduction and reversion in the North American Salicales. Ann. Bot. Lond. **26,** 165–73; 1912.

987. Holden, R. Some features in the anatomy of the Sapindales. Bot. Gaz. **53**, 50–7; 1912.

988. Hollendonner, F. Über die Anatomie des Stengels von *Alyssum arduini*. Hungarian with German summary. Bot. Közl. **8**, 26–40; 1909. *See* Just's Jber., Pt. 1, 986; 1909.

989. Holm, T. Supplementary note on the stem-structure of *Phytolacca*. Merck's Rep. **20**, 218; 1911. *See* Bot. Zbl. **117**, 606; 1911.

990. —— Studies in the Compositae. Amer. Midl. Nat. **10**, 1–17; 1926.

991. —— *Nyssa sylvatica* Marsh. Amer. Midl. Nat. **1**, 128–37; 1909. *See* Just's Jber., Pt. 1, 995; 1909.

992. —— *Comandra umbellata* (L.) Nutt. Amer. Midl. Nat. **9**, 1–11; 1924. *See* Just's Jber. 321; 1924.

993. —— *Apios tuberosa* Moench. Amer. Midl. Nat. **9**, 118–36; 1924. *See* Just's Jber. 321; 1924.

994. —— *Euphorbia marylandica* Greene. Amer. Midl. Nat. **9**, 151–74; 1924.

995. —— *Polygonum*: Sectio Tovara. Bot. Gaz. **84**, 1–26; 1927.

996. —— *Anemonella thalictroides* (L.) Spach. An anatomical study. Amer. J. Science, **4**, 243–8; 1907. *See* Just's Jber., Pt. 1, 444; 1908.

997. —— *Isopyrum biternatum* Torr. et Gr.; an anatomical study. Amer. J. Science, **6**, 133–40; 1908. *See* Just's Jber., Pt. 1, 436; 1908.

998. —— *Gerardia* L. and *Buchera* L. with supplementary notes on *Gratiola*: an anatomical study. Amer. J. Science, **18**, 401–11; 1929.

999. —— Medullary cork in *Balsamocitrus*. An anatomical study. Amer. J. Science, Ser. 5, **18**, 505–8; 1929.

1000. —— Anatomy of certain species of *Ilex* of the sections *Aquifolium* and *Prinos*. Amer. J. Science, Ser. 5, **18**, 497–504; 1929.

1001. —— Morphology of North American species of *Polygala*. Bot. Gaz. **88**, 167–85; 1929.

1002. —— *Phryma leptostachya* L. A morphological study. Bot. Gaz. **56**, 306–18; 1913.

1003. —— A morphological study of *Cicer arietinum*. Bot. Gaz. **70**, 446–52; 1920.

1004. —— Morphological study of *Carya alba* and *Juglans nigra*. Bot. Gaz. **72**, 375–89; 1921.

1005. —— *Chionophila* Benth. A morphological study. Amer. J. Science, Ser. 5, **1**, 31–8; 1921. *See* Just's Jber., Pt. 2, 73; 1921.

1006. —— *Dirca palustris* L. A morphological study. Amer. J. Science, Ser. 5, **1**, 31–8; 1921 and **2**, 177–82; 1921. *See also* Just's Jber., Pt. 2, 73; 1921.

1007. —— *Chenopodium ambrosioides* L. A morphological study. Amer. J. Science, Ser. 5, **6**, 157–67; 1923. *See* Just's Jber., Pt. 1, 672; 1923.

1008. —— *Chelone glabra* L. A morphological study. Amer. J. Science, Ser. 5, **6**, 265–70; 1923. *See* Just's Jber., Pt. 1, 672; 1923.

1009. —— *Gratiola* and *Sophronanthe* Benth. A morphological study. Amer. J. Science, **7**, 132–40; 1924. *See* Just's Jber. 321; 1924.

1010. —— *Polypremum procumbens* L. A morphological study. Amer. J. Science, **7**, 209–18; 1924. *See* Just's Jber. 321; 1924.

1011. —— *Ilysanthes*, *Scrophularia*, and *Linaria*. A morphological study. Amer. J. Science, **8**, 395–410; 1924. *See* Just's Jber. 321; 1924.

1012. —— *Saururus cernuus* L. A morphological study. Amer. J. Science, Ser. 5, **12**, 162–8; 1926. *See* Just's Jber., Pt. 2, 442; 1926.

1013. —— *Leptandra* and *Veronica*. A morphological study. Amer. J. Science, Ser. 5, **9**, 460–71; 1925. *See* Just's Jber., Pt. 2, 441; 1926.

1014. —— *Boehmeria cylindrica* (L.) Sw. A morphological study. Amer. J. Science, Ser. 5, **13**, 115–22; 1927. *See* Just's Jber., Pt. 1, 942; 1927.

—— Medicinal plants of North America:

1015. 1. *Aconitum uncinatum* Linn. Merck's Rep. **16**, 65–7; 1907. *See* Just's Jber., Pt. 1, 436; 1908.

1016. 2. *Caulophyllum thalictroides* (L.) Mich. Merck's Rep. **16,** 94–6; 1907. *See* Just's Jber., Pt. 1, 437; 1908 and Bot. Zbl. **105,** 128; 1907.

1017. 3. *Jeffersonia diphylla* (L.) Pers. Merck's Rep. **16,** 125–7; 1907. *See* Bot. Zbl. **105,** 506; 1907.

1018. 4. *Polygala senega* L. Merck's Rep. **16,** 155–7; 1907. *See* Just's Jber., Pt. 1, 437; 1908 and Bot. Zbl. **105,** 207; 1907.

1019. 5. *Cunila mariana* L. Merck's Rep. **16,** 188–9; 1907. *See* Bot. Zbl. **106,** 506–7; 1907.

1020. 8. *Aristolochia serpentaria*. Merck's Rep. **16,** 276–9; 1907. *See* Bot. Zbl. **107,** 204; 1908.

1021. 9. *Podophyllum decandra* L. Merck's Rep. **16,** 250–2; 1907. *See* Just's Jber., Pt. 1, 438; 1908.

1022. 10. *Lobelia inflata* L. Merck's Rep. **16,** 341–3; 1907. *See* Just's Jber., Pt. 1, 439; 1908 and Bot. Zbl. **108,** 204; 1908.

1023. 11. *Gaultheria procumbens* L. Merck's Rep. **17,** 1–14; 1908. *See* Just's Jber., Pt. 1, 439; 1908 and Bot. Zbl. **108,** 205; 1908.

1024. 12. *Liquidambar styraciflua* L. Merck's Rep. **17,** 31–4; 1908.

1024A. 14. *Gelsemium sempervirens* Ait. Merck's Rep. **17,** 86–9; 1908. *See* Just's Jber., Pt. 1, 441; 1908 and Bot. Zbl. **108,** 207; 1908.

1025. 15. *Hedeoma pulegioides* Pers. Merck's Rep. **17,** 115–17; 1908. *See* Bot. Zbl. **108,** 367; 1908.

1026. 17. *Geranium maculatum* L. Merck's Rep. **17,** 172–5; 1908. *See* Just's Jber., Pt. 1, 442; 1908 and Bot. Zbl. **108,** 368; 1908.

1027. 18. *Sanguinaria canadensis* L. Merck's Rep. **17,** 209–12; 1908. *See* Just's Jber., Pt. 1, 442; 1908.

1028. 19. *Gillenia trifoliata* Moench. Merck's Rep. **17,** 234–6; 1908. *See* Bot. Zbl. **110,** 31–2; 1909.

1029. 20. *Cimicifuga americana* Nutt. Merck's Rep. **17,** 262–5; 1908. *See* Just's Jber., Pt. 1, 443; 1908.

1030. 21. *Baptisia tinctoria* R.Br. Merck's Rep. **17,** 295–7; 1908. *See* Just's Jber., Pt. 1, 444; 1908 and Bot. Zbl. **110,** 110–11; 1909.

1031. 22. *Eupatorium perfoliatum* L. Merck's Rep. **17,** 326–8; 1908.

1032. 23. *Sassafras officinale* Nees. Merck's Rep. **18,** 3–6; 1909. *See* Just's Jber., Pt. 1, 988; 1909.

1033. 26. *Collinsonia canadensis* L. Merck's Rep. **18,** 87–90; 1909. *See* Bot. Zbl. **111,** 490–1; 1909.

1034. 28. *Chimaphila umbellata* L. Merck's Rep. **18,** 143–5; 1909. *See* Just's Jber., Pt. 1, 990; 1909.

1035. 29. *Euonymus americanus* L. and *E. atropurpureus* Jacq. Merck's Rep. **18,** 169–71; 1909. *See* Just's Jber., Pt. 1, 991; 1909 and Bot. Zbl. **111,** 492; 1909.

1036. 30. *Liriodendron tulipifera* L. Merck's Rep. **18,** 198–201; 1909. *See* Just's Jber., Pt. 1, 991; 1909.

1037. 31. *Diospyros virginiana* L. Merck's Rep. **18,** 129–31; 1909. *See* Just's Jber., Pt. 1, 992; 1909.

1038. 32. *Sambucus canadensis*. Merck's Rep. **18,** 259–62; 1909. *See* Just's Jber., Pt. 1, 993; 1909.

1039. 33. *Prunus serotina* Ehrh. Merck's Rep. **18,** 287–90; 1909. *See* Bot. Zbl. **113,** 558–9; 1910.

1040. 34. *Cornus florida* L. Merck's Rep. **18,** 318–21; 1909. *See* Just's Jber., Pt. 1, 994; 1909.

1041. 35. *Quercus alba* L. Merck's Rep. **19,** 2–4; 1910. *See* Bot. Zbl. **114,** 600–1; 1910.

1042. 38. *Rhus toxicodendron* L. Merck's Rep. **19,** 65–8; 1910. *See* Bot. Zbl. **114,** 602–3; 1910.

1043. 39. *Euphorbia corollata* L. Merck's Rep. **19,** 126–8; 1910. *See* Bot. Zbl. **114,** 603–4; 1910.

1044. 41. *Glechoma hederacea* L. Merck's Rep. **19,** 194–6; 1910. *See* Bot. Zbl. **114,** 605; 1910.

1045. 42. *Rubus villosus* Ait. Merck's Rep. **19,** 217–20; 1910. *See* Bot. Zbl. **114,** 605; 1910.

1046. 43. *Solanum carolinense* L. Merck's Rep. **19,** 249; 1910. *See* Bot. Zbl. **114,** 606; 1910.

1047. 44. *Apocynum cannabinum* L. Merck's Rep. **19,** 277–80; 1910. *See* Bot. Zbl. **116,** 382; 1910.

1048. 45. *Grindelia squarrosa* (Pursh.) Dunal. Merck's Rep. **19,** 310–12; 1910. *See* Bot. Zbl. **116,** 383; 1911.

1049. 46. *Rhus glabra* L. Merck's Rep. **19,** 338–40; 1910. *See* Bot. Zbl. **116,** 383; 1911.

1050. 47. *Coptis trifolia* Salisb. With supplementary note on the seedlings of *Cimicifuga racemosa* Nutt. Merck's Rep. **20,** 4–6; 1911. *See* Bot. Zbl. **118,** 95; 1911.

1051. 48. *Stillingia sylvatica* L. Merck's Rep. **20,** 36–8; 1911. *See* Bot. Zbl. **116,** 590; 1911.

1052. 50. *Arctostaphylos uva-ursi* Spreng. Merck's Rep. **20,** 95–6; 1911. *See* Bot. Zbl. **117,** 397; 1911.

1053. 51. *Ilex opaca* Ait. Merck's Rep. **20,** 124–6; 1911. *See* Bot. Zbl. **117,** 398; 1911.

1054. 52. *Monarda punctata* L. Merck's Rep. **20,** 154–6; 1911. *See* Bot. Zbl. **117,** 398; 1911.

1055. 53. *Asarum canadense* L. Merck's Rep. **20,** 185; 1911. *See* Bot. Zbl. **117,** 605; 1911.

1056. 54. *Cephalanthus occidentalis* L. Merck's Rep. **20,** 216–18; 1911. *See* Bot. Zbl. **117,** 605; 1911.

1057. 68. *Saponaria officinalis* L. Merck's Rep. **22,** 9–12; 1913. *See* Just's Jber., Pt. 2, 1075; 1913 and Bot. Zbl. **125,** 77; 1914.

1058. 69. *Viburnum prunifolium* L. Merck's Rep. **22,** 35–6; 1913. *See* Just's Jber., Pt. 2, 1075; 1913 and Bot. Zbl. **125,** 77; 1914.

1059. 70. *Leptandra virginica* (L.) Nutt. Merck's Rep. **22,** 61–4; 1913. *See* Bot. Zbl. **125,** 48; 1914.

1060. 71. *Datura Stramonium* L. Merck's Rep. **22,** 87–91; 1913. *See* Just's Jber., Pt. 2, 1075; 1913 and Bot. Zbl. **125,** 78; 1914.

1061. 73. *Epigaea repens* L. Merck's Rep. **22,** 144–6; 1913. *See* Just's Jber., Pt. 2, 1075; 1913 and Bot. Zbl. **125,** 79; 1914.

1062. 74. *Ranunculus bulbosus* L. Merck's Rep. **22,** 178–80; 1913. *See* Bot. Zbl. **125,** 79; 1914.

1063. 75. *Hydrastis canadensis.* Merck's Rep. **22,** 202–4; 1913. *See* Bot. Zbl. **126,** 59; 1914.

1064. 76. *Rhamnus Purshiana* DC. Merck's Rep. **22,** 232–5; 1913. *See* Bot. Zbl. **126,** 59; 1914.

1065. 77. *Solidago odora* Ait. Merck's Rep. **22,** 252–4; 1913. *See* Bot. Zbl. **126,** 60; 1914.

1066. 78. *Menispermum canadense* L. Merck's Rep. **22,** 281–4; 1913. *See* Bot. Zbl. **126,** 60; 1914.

1067. 80. *Verbascum thapsus* L. Merck's Rep. **23,** 4–5; 1914. *See* Bot. Zbl. **126,** 61–2; 1914.

1068. 85. *Hepatica triloba* Chaix var. *americana* DC. Merck's Rep. **23,** 293–5; 1914. *See* Bot. Zbl. **129,** 187; 1915.

1069. 88. *Castanea dentata* (Marsh.) Borkh. and *C. pumila* (L.) Mill. Merck's Rep. **24,** 85–7; 1915. *See* Bot. Zbl. **129,** 188–9; 1915.

1070. 95. *Petiveria alliaceae* L. Merck's Rep. **24,** 266–70; 1915. *See* Bot. Zbl. **131,** 351; 1916.

1071. 97. *Aralia* and *Panax.* Merck's Rep. **25,** 11–15, 62–5, 126–30, 177–80; 1916 and **26,** 6–8; 1917. *See* Just's Jber. 594; 1922.

1072. 98. *Ambrosia artemisaefolia* L. and *A. trifida* L. Merck's Rep. **26,** 62–5, 120–2, 179–80; 1917. *See* Just's Jber. 594; 1922.

1073. 99. *Cissampelos Pareira* L. Merck's Rep. **27,** 60–1; 1918. *See* Just's Jber. 594; 1922.

1074. 100. *Juglans nigra* L. and *J. cinerea* L. Merck's Rep. **27,** 115–17 and 168–70; 1918. *See* Just's Jber. 594; 1922.

1075. HOLMES, E. M. Spurious Quillaia bark. Pharm. J., Ser. 4, **22,** 315; 1906.

1076. —— Quillaia bark. Pharm. J., Ser. 4, **30,** 79; 1910.

1077. HOLMES, M. G. A study in the anatomy of hazel-wood with reference to conductivity of water. Ann. Bot. Lond. **32,** 553–67; 1918.

1078. —— Observations on the anatomy of ash-wood, with reference to water-conductivity. Ann. Bot. Lond. **33,** 255–64; 1919.

1079. —— The study of water conductivity in sycamore wood. Ann. Bot. Lond. **35,** 251–68; 1921.

1080. HOLMGREEN, J. Några jaktagelser öfver förekomsten af pärlhår hos Tropiska växter. Svensk. bot. Tidskr. **5,** 197–216; 1911. *See* Just's Jber., Pt. 2, 1052; 1911.

1081. HOLROYD, R. Morphology and physiology of the axis in Cucurbitaceae. Bot. Gaz. **78,** 1–44; 1924.

1082. HONER, L. D., and MILLER, P. A. A histological study of *Eriodictyon californicum* II. J. Amer. pharm. Ass. Sci. Ed. **33,** 379–82; 1944.

1083. HOPKINSON, A. D. Beiträge zur Mikrographie tropischer Hölzer. Beih. bot. Zbl. **29,** 2. 441–56; 1912.

1084. HORN, E. F. New uses for Brazilian timbers. Trop. Woods, **86,** 12–13; 1946.

1085. HORST, W. A. Studien über den Gambohanf. Faserforschung, **4,** 61–124; 1924.

1086. HOSSEUS, C. C. *Rheum palmatum* die Stammpflanze des guten offizinellen Rhabarbers. Arch. Pharm. Berl. **249,** 6. 419–24; 1911.

1087. HOUGHTALING, H. B. Stem morphogenesis in *Lycopersicum.* A quantitative study of cell size and number in the tomato. Bull. Torrey bot. Cl. **67,** 33–55; 1940.

1088. HOWARD, A. *A manual of the timbers of the world.* London, pp. 751; 1948.

1089. —— *Studies of the identification of timbers, with a note on the seasoning of wood.* London, pp. 110; 1942.

1090. —— *Supplement to studies of the identification of timbers.* London, pp. 19; 1943.

HOWARD, R. A. Studies of the Icacinaceae:

1091. I. Preliminary taxonomic notes. J. Arnold Arbor. **21,** 461–89; 1940.

1092. II. *Humiranthera, Leretia, Mappa* and *Nothapodytes,* valid genera of the Icacinaceae. J. Arnold Arbor. **23,** 55–79; 1942.

1093. III. A revision of *Emmotum.* J. Arnold Arbor. **23,** 479–94; 1942.

1094. IV. Consideration of the New World genera. Contr. Gray Herb. Harv. **142,** 3–60; 1942.

1095. V. A revision of the genus *Citronella* D. Don. Contr. Gray Herb. Harv. **142,** 61–88; 1942.

1096. VI. *Irvingbaileya* and *Codiocarpus,* two new genera of the Icacinaceae. Brittonia N.Y. **5,** 47–55; 1943.

1097. VII. A revision of the genus *Medusanthera* Seeman. Lloydia, **6,** 133–44; 1943.

1098. VIII. Brief notes on some Old World genera. Lloydia, **6,** 144–54; 1943.

1099. Howell, J. T. Concerning stomata on leaves in *Arctostaphylos*. Wasmann Collector, **6,** 57–63; 1945. *See* Biol. Abstr. **20,** No. 10931; 1946.

1100. Hryniewiecki, B. Ein neuer Typus der Spaltöffnungen bei den Saxifragaceen. Bull. internat. Acad. Sci. Cracovie Cl. Sci. Mathem.-Nat., Ser. B, 52–73; 1912.

1101. —— Anatomische Studien über die Spaltöffnungen bei den Dicotylen. Bull. internat. Acad. Sci. Cracovie Cl. Sci. Mathem.-Nat., Ser. B, 585–605; 1912. *See* Just's Jber., Pt. 2, 806; 1912.

1102. Huber, B. Die physiologische Bedeutung der Ring- und Zerstreutporigkeit. Ber. dtsch. bot. Ges. **53,** 711–19; 1935.

1103. —— Botanik und koloniale Holzforschung. Kolonialforstl. Mitt. **1,** 163–9; 1938.

1104. Huber, J. A. Fensterblätter. Z. Sukkulentenk. **1,** 95–6; 1923.

1105. Hubert, G. Des Verbenacées utilisées en matière medicale. Trav. Lab. Mat. méd. Paris, **13,** pp. 128; 1921.

1106. Hülsbruch, W. Beiträge zur Kenntnis der Gattung *Dysophylla* und einiger anderer Labiaten. Flora, Jena, n.s. **26,** 329–62; 1932.

1107. Humbert, H. Sur deux types de structure unifaciale de la feuille chez des *Senecio* malgaches. C. R. Acad. Sci. Paris, **184,** 42–4; 1927. *See* Bot. Zbl., n.f. **10,** 72; 1927.

1108. —— Sur un *Brachylaena* nouveau exploité comme Santal de Madagascar. Bull. Soc. bot. Fr. **84,** 203–9; 1937.

1109. Hummel, F. C. The formation of growth rings in *Entandrophragma macrophyllum* A. Chev. and *Khaya grandifoliola* C. DC. Emp. For. Rev. **25,** 103–7; 1946.

1110. Humphrey, R. R. A study of *Idria columnaris* and *Fouquiera splendens*. Amer. J. Bot. **22,** 2. 184–206; 1935.

1111. Hunter, C. The aerating system of *Vicia faba*. Ann. Bot. Lond. **29,** 627–34; 1915.

1112. Hunziker, J. *Beiträge zur Anatomie von Rafflesia patma* Bl. Thesis, Zürich, pp. 75; 1920.

1113. Hutchinson, J. *The families of flowering plants. I. Dicotyledons.* London, pp. 328; 1926.

1113a. —— Zombiana, the supposed tropical African member of the Myoporaceae. Kew Bull. No. 6, 236–7; 1930.

1114. —— Neglected generic characters in the family Cornaceae. Ann. Bot. Lond., n.s. **6,** 83–93; 1942.

1115. —— *Macrozanonia* Cogn. and *Alsomitra* Roem. Ann. Bot. Lond., n.s. **6,** 95–102; 1942.

1116. Hutchinson, J., and Dalziel, J. M. *Flora of West Tropical Africa.* Vol. i, pp. 523; Vol. ii, pp. 651; 1927–36.

1117. Hyde, K. C. Tropical light-weight woods. Bot. Gaz. **79,** 380–411; 1925.

1118. Imamura, S. J. Über *Hydrobium japonicum* Imamura, eine neue Podostemonacee in Japan. Bot. Mag. Tokyo, **43,** 332–9; 1929.

1119. International Association of Wood Anatomists. Glossary of terms used in describing woods. Trop. Woods, **36,** 1–13; 1933.

1120. —— Standard terms of length of vessel members and fibres. Trop. Woods, **51,** 21; 1937.

1121. —— Standard terms of size for vessel diameter and ray width. Trop. Woods, **59,** 51–2; 1939.

1122. Irmscher, E. *Begoniaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

1123. Ironside, A. F. The anatomical structure of the New Zealand Piperaceae. Trans. N. Zealand Inst. **44,** 339–48; 1912 (1911). *See* Just's Jber., Pt. 2, 1074; 1911.

1124. Isenberg, I. H. Microchemical studies of tyloses. J. For. **31,** 961–7; 1933.

1125. Issatschenko, B. L. Über die Wurzelknöllchen bei *Tribulus terrestris* L. (Russian with German summary.) Bull. Jard. bot. St. Petersb. **13,** 23–31; 1913.

1126. Iterson, G. van, Jun. The significance of the anatomy of wood for the preservation of marine structures against the shipworm (Teredo). Proc. 5th Pacific Sci. Congress, Victoria and Vancouver, B.C., Canada, 3907–11; 1934.

1127. —— Wood anatomy and resistance to shipworm attack. Nature, Lond. **137,** 196; 1936.

1128. Iwanowa-Paroiskaja, M. Zur Anatomie des *Ricinus* als Textilpflanze. Bull. Univ. Asie. centr. **15,** 97–115; 1927. *See* Just's Jber., Pt. 1, 977; 1927 and Bot. Zbl., N.F. **11,** 451; 1928.

1129. Jablonszky, E. *Euphorbiaceae-Phyllanthoideae-Bridelieae* in Engler's *Das Pflanzenreich*, iv. 147; viii; 1915.

1130. Jaccard, P. Nombre et dimensions des rayons médullaires chez *Ailanthus glandulosa*. Bull. Soc. vaud. Sci. nat. **54,** 253–62; 1922.

1131. —— Structure anatomique et valeur technique du bois. Ber. Eidg. Materialprüf. u. Versuchsanst. Zürich. 1–20; 1934.

1132. —— Mikroskopische Holzstruktur und Holzbestimmung. Schweiz. z. Forstw. **87,** 41–54 and 65–82; 1936.

1133. —— Sur les épaissements spirales et les striations des parois des fibres, des vaisseaux ou des trachéides du bois et leur signification. Bull. Soc. Bot. Suisse, **50,** 285–92; 1940.

1134. —— Evolution morphologique de la flore et structure anatomique du bois. Bull. Soc. vaud. Sci. nat. **62,** 273–86; 1943.

1135. Jacobs, B. *Digitalis ambigua*. J. Amer. pharm. Ass. **30,** 21; 1941. *See* Quart. J. Pharm. **14,** 298; 1941.

1136. Jacobs, M. R. *Field studies on the gum veins in the Eucalypts*. Bull. For. Bur. Aust., No. 20, pp. 36; 1937.

1137. Jacobsohn-Stiasny, E. Versuch einer histologisch-phylogenetischen Bearbeitung der Papilionaceae. S. B. Akad. Wiss. Wien, **122,** 1. 1091–1153; 1913. *See* Just's Jber., Pt. 2, 1078; 1913.

1138. Jadin, F. Contribution à l'étude des Simarubacées. Ann. Sci. nat. b., Sér. **8,** 13. 201–304; 1901.

1139. Jadin, F., and Juillet, A. Recherches anatomiques sur trois espèces de *Kalanchoë* de Madagascar, donnant des résines parfumées dans leurs écorces. Ann. Mus. colon. Marseille, Sér. 2, **10,** 137–56; 1912. *See* Just's Jber., Pt. 2, 807; 1912.

1140. Jaeger, P. Particularités cytologiques relative à l'état de l'oxalate de calcium dans l'écorce de la racine du *Piscidia erythrina* Lam. Bull. Soc. bot. Fr. **87,** 130–3; 1940.

1141. Jager, F. K. H., and Jakolev, M. S. Condition of starch in potato at different stages of tuber ripening. C. R. Acad. Sci. U.R.S.S. **23,** 491–94; 1939.

1142. Janchen, E. *Cistaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1923.

1143. Janda, C. Die extranuptialen Nektarien der Malvaceen. Öst. bot. Z. **86,** 2. 81–130; 1937.

1144. Jane, F. W. The structure of timbers in relation to their uses. J. Quekett micr. Cl. **99,** 277–300; 1933.

1145. —— Terminal and initial parenchyma in wood. Nature, Lond. **133,** 534; 1934.

1146. —— Aspects of the study of wood anatomy. Sci. Progr. Twent. Cent. **111,** 439–55; 1934.

1147. Janssonius, H. H. Mikrographie einiger technisch wichtigen Holzarten aus Surinam. Verh. Akad. Welt. Amst. **18,** 3–50; 1914.

1148. —— Mucilage and oil cells in the woods of the Lauraceae. Trop. Woods, **6,** 3–4; 1926.

1149. —— De Slijm- en Oliecellen in het hout der Lauraceae in verband met de zienswijze van Tschirch. Pharm. Weekbl. **39,** 1053–5; 1927.

1150. Janssonius, H. H. On the suitability of certain Euphorbiaceous woods for paper pulp. Trop. Woods, **18**, 1–3; 1929.

1151. —— A contribution to the natural classification of the Euphorbiaceae. Trop. Woods, **19**, 8–10; 1929.

1152. —— Die Verteilung des stockwerkartigen Aufbaues im Holz der Dikotylen. Rec. Trav. bot. néerland. **28**, 97–106; 1931.

1153. —— Note on the wood of the genus *Gironniera*. Trop. Woods, **29**, 28–9; 1932.

1154. —— *Mikrographie des Holzes der auf Java vorkommenden Baumarten.* 6 vols. Leiden, 1906–36.

1155. —— *Anatomische Bestimmungstabelle für die Javanischen Hölzer.* Leiden, pp. 236; 1940.

1156. Janssonius, H. H., and Moll, J. W. Der anatomische Bau des Holzes der Pfropfhybride *Cytisus Adami* und ihrer Komponente. Rec. Trav. bot. néerland. **8**, 333–68; 1911.

1157. Jauch, B. Quelques points de l'anatomie et de la biologie des Polygalacées. Bull. Soc. bot. Genève, Sér. 2, **10**, 47–84; 1918.

1158. Jay, B. A. The anatomy of some lauraceous scent-yielding woods known as 'medang'. Kew Bull. No. 1, 66–72; 1936.

1159. Jayawardana, C. P. The anatomical structure of certain Ceylon woods. Ann. Roy. bot. Gdns. Paradeniya, **11**, 307–17; 1932.

1160. Jayme, G. Erzeugung und Eigenschaften von Laubholzzellstoffen. Silvae Orbis, **15**, 178–212; 1944.

1161. Jean, M. *Essai sur l'anatomie comparée du liber interne dans quelques familles de dicotylédones. Étude des plantules.* Thesis, Paris, pp. 355; 1927.

1162. Jeffrey, E. C. The morphology of the central cylinder of the angiosperms. Trans. Canad. Inst. 1–40; 1899.

1163. —— *The anatomy of woody plants.* Chicago, pp. 478; 1922.

1164. —— The cytology of vegetable crystals. Science, **55**, 566–7; 1922.

1165. —— Professor Lloyd and vegetable crystals. Science, **57**, 442–4; 1923.

1166. —— The origin of parenchyma in geological time. Proc. nat. Acad. Sci. Wash. **11**, 106–10; 1925.

1167. Jeffrey, E. C., and Cole, R. D. Experimental investigations of the genus *Drimys*. Ann. Bot. Lond. **30**, 359–68; 1916.

1168. Jeffrey, E. C., and Torrey, R. E. Transitional herbaceous dicotyledons. Ann. Bot. Lond. **35**, 227–47; 1921.

1169. —— Physiological and morphological correlations in herbaceous angiosperms. Bot. Gaz. **71**, 1–30; 1921.

1170. Jenkins, W. A. A histological study of snap bean tissues affected with black rot. J. Agric. Res. **62**, 683–90; 1941.

Jentsch, F., *et al.*

(and Appel, E.). Beschreibung tropischer Hölzer aus dem Urwalde Kameruns:

1171. Terminalia superba, Pycnanthus kombo, Staudtia Kamerunensis, Symphonia gabonensis. Z. Weltforstwirtschaft, **3**, 110–20; 1936.

1172. Aucoumea Klaineana, Triplochiton scleroxylon, Mimusops Djave. **3**, 235–46; 1936.

1173. Rhizophora mangle, Lophira procera, Chlorophora excelsa, Musanga smithii. **3**, 331–41; 1936.

(with Appel, E. and Schmidt, E.)

1174. Irvingia gabonensis, Sterculia oblonga, S. rhinopetala, Pterygota macrocarpa. **3**, 497–506; 1936.

1175. Enantia chlorantha, Alstonia congensis, Kickxia elastica, Rauwolfia macrophylla. **4**, 35–45; 1936.

1176. Copaifera tessmannii, Daniellia oblonga, Oxystigma mannii. **4**, 515–24; 1936.

1177. Andira inermis, Pterocarpus soyauxii, Chrysophyllum africanum, Xylopia striata. Kolonial forst. Mitt. **1,** 235–45; 1938.

1178. Coula edulis, Strombosia glaucescens, Strombosiopsis tetrandra, Mammea eborro. **1,** 425–32; 1939.

1179. Jepson, W. L. Regeneration in Manzanita. Madroño, S. Francisco, **1,** 3–11; 1916.

1180. —— *Flora of California.* Berkeley, Cal. II. iii. 219–22; 1936 and III. i. 29–32, 290–5; 1936.

1181. Jimbo, T. Physiological anatomy of the root-nodule of *Wistaria sinensis.* Proc. imp. Acad. Japan, **3,** 164–6; 1927. *See* Jap. J. Bot. **3,** Abs. No. 252; 1926.

1182. Jodin, H. Recherches anatomiques sur les Boraginées. Ann. Sci. nat. b., Sér. 8, **17,** 263–346; 1903.

1183. Johnson, D. S. Studies of the development of the Piperaceae. The structure and seed-development of *Peperomia hispidula.* Amer. J. Bot. **1,** 323–39 and 357–97; 1914.

1184. —— The development of the shoot, male flower and seedling of *Batis maritima* Linn. Bull. Torrey bot. Cl. **62,** 19–31; 1935.

1185. Johnson, E. D. A comparison of the juvenile and adult leaves of *Eucalyptus globulus.* New Phytol. **25,** 202–12; 1926.

1186. Johnson, M. A. The origin of the foliar pseudo-bulbils in *Kalanchoë daigremontiana.* Bull. Torrey bot. Cl. **61,** 355–65; 1934.

1187. Jolivet, R. Contribution à l'étude des genêts indigènes. Trav. Lab. Mat. méd. Paris, **16,** pp. 122; 1925.

1188. Jolly, N. W. *The structure and identification of Queensland woods.* For. Bull. Qd., No. 1, pp. 14; 1917.

1189. Jones, W. N. Root-cap development in *Calluna vulgaris.* Nature, Lond. **116,** 677; 1925.

1190. Jones, W. R. The development of the vascular structure of *Dianthera americana.* Bot. Gaz. **54,** 1–30; 1912.

1191. Jones, W. S. *Timbers, their structure and identification.* Oxford, pp. 148; 1924.

1192. Jönsson, B. Siebähnliche Poren in den trachealen Xylemelementen der Phanerogamen, hauptsächlich der Leguminoseen. Ber. dtsch. bot. Ges. **10,** 494–513; 1892.

Joshi, A. C. Contributions to the anatomy of Chenopodiaceae and Amarantaceae:

1193. I. Anatomy of *Alternanthera sessilis* R.Br. J. Indian bot. Soc. **10,** 221–31; 1931.

1194. II. Primary vascular system of *Achyranthes aspera* L., *Cyathula prostrata* Blume and *Pupalia lappacea* Juss. J. Indian bot. Soc. **10,** 265–92; 1931.

1195. —— Structure, arrangement and course of vascular bundles in the stem and leaves of *Heptapleurum venulosum* Seem. J. Indian bot. Soc. **11,** 73–81; 1932.

1196. —— Variations in the medullary bundles of *Achyranthes aspera* L. and the original home of the species. New Phytol. **33,** 53–7; 1934.

1197. —— Secondary thickening in the stem and root of *Stellera chamaejasmae* Linn. Proc. Indian Acad. Sci. **2,** 5. 424–36; 1935.

1198. —— The anatomy of *Rumex* with special reference to the morphology of the internal bundles and the origin of the internal phloem in the Polygonaceae. Amer. J. Bot. **23,** 5. 362–9; 1936.

1199. —— Some salient points in the evolution of the secondary cylinder of Amarantaceae and Chenopodiaceae. Amer. J. Bot. **24,** 3–9; 1937.

1200. Jost, L. Die Determinierung der Wurzelstruktur. Z. Bot. **25,** 481–522; 1932.

1201. Jovet-Ast, S. Quelques resemblances et différences anatomiques entre *Astiella* P. J. et trois genres voisins. Phanérogamie (Notulae systematicae), **10,** 1–2. 53–6; 1941.

1202. Juillet, A., Galavielle, L., and Ancelin, M. Système sécréteur des organes végétatifs du pyrèthre de Dalmatie. Bull. Soc. Pharmac. **28,** 449–59; 1921.

1203. Julg, E. Über das angebliche Vorkommen von Bakterien in den 'Wurzelknöllchen' der Rhinanthaceen. Ber. dtsch. bot. Ges. **34,** 427–39; 1916.

1204. Juliano, J. B. Anatomy and morphology of the Bunga; *Aeginetia indica* Linnaeus. Philipp. J. Sci. **56,** 405–51; 1935.

1205. Kamerling, Z. Sind die Knollen von *Batatas edulis* Choisy Wurzeln oder Stengeln? Ber. dtsch. bot. Ges. **32,** 352–60; 1914.

1206. Kanehira, R. *Anatomical characters and identification of Formosan woods.* Taihoku, pp. 317; 1921.

1207. —— *Anatomical notes on Indian woods.* Bull. Dept. For. Formosa, No. 4, pp. 40; 1924.

1208. —— *Identification of Philippine woods by anatomical characters.* Govt. Res. Inst. Formosa Publ., pp. 73; 1924.

1209. —— *Anatomical characters and identification of the important woods of the Japanese Empire.* Taihoku, pp. 297; 1926.

1210. —— Note on the identity of the Chinese 'Pau-Hoi'. Trop. Woods, **10,** 53–4; 1927.

1211. —— True 'Pau-Hoi' tree of China. A new species. Trop. Woods, **23,** 8; 1930.

1212. —— On a light-weight wood, drifted on the shores of the Caroline Islands. J. For. Soc. Jap. **15,** 113–16; 1933.

1213. —— On the foreign fancy woods in Japan. J. For. Soc. Jap. **20,** 56–66; 1938.

1214. Kanehira, R., Yatsutake, K., and Shigematsu, M. On light-weight woods. J. For. Soc. Jap. **15,** 601–15; 1933.

1215. Kaneshi, C. Die Untersuchungen über die Grundlage der Holzidentifizierungsmethode. I. Die Markstrahlen des Laubholzes und ihre Bauarten. J. For. Soc. Jap., **10,** 7–30; 1928.

1216. Kangiesser, F., and Leiningen, W. Graf. Z. Über Alter und Dickenzuwachs von Kleinsträuchern. Ber. bayr. Ges. **12,** 104–11; 1910. *See* Just's Jber., Pt. 2, 1585; 1910.

1217. Kano, R. Vergleichende Anatomie über die Gattung *Acanthopanax* und die nahe verwandten Gattungen. Jap. J. bot. **8,** 3. 215–68; 1936.

1218. —— Über ein neues mechanisches Gewebe in den Blättern der *Cornus*-Arten. Bot. Mag. Tokyo, **51,** 926–30; 1937.

1219. Kapustinskii, A. The present state of the parasitological method in taxonomic studies, and the possibilities of its future development. J. Bot. U.R.S.S., **24,** 168–73; 1939. *See* Biol. Abstr. **16,** No. 2257; 1942.

1220. Karling, J. S. The laticiferous system of *Achras Zapota* L. I. A preliminary account of the origin, structure and distribution of the latex vessels in the apical meristem. Amer. J. Bot. **16,** 803–24; 1929.

1221. Karsten, G., and Benecke, W. *Lehrbuch der Pharmacognosie.* Jena, pp. 426; 1928.

1222. Kassner, H. C. *The histological and chemical examination of the seeds of Ipomoea hederacea Jacquin and other species of Ipomoea.* Thesis, London, pp. 70; 1924.

1223. Kastory, A., and Namylowsky, B. O budowie anatomicznej *Actinidia colonicata* i *arguta*. Kosmos, Lwów, **38,** 1146–56; 1913. *See* Just's Jber., Pt. 2, 1079; 1913.

1224. Kean, Ch. I. The morphology and physiology of the leaves of some Crassulaceae. Trans. bot. Soc. Edinb. **29,** 96–104; 1924 (1927).

1225. —— Anatomy of the genus *Mesembryanthemum.* I. Root. Trans. bot. Soc. Edinb. **29,** 381–8; 1927.

1226. —— Light receptors in *Mesembryanthemum.* Trans. bot. Soc. Edinb. **30,** 37–42; 1931.

1227. —— Artificial crystals in preserved tissue of *Mesembryanthemum.* Trans. bot. Soc. Edinb. **30,** 43–5; 1931.

1228. Kearny, T. H. The plant covering of Ocracoke Island; a study in the ecology of the North Carolina strand vegetation. Contr. U.S. nat. Herb. **5,** 261–319; 1900.

1229. Keen, G. R. *Aeroplane timbers.* London, pp. 78; 1919.

1230. Keller, B. Halophyten und Xerophyten Studien. J. Ecol. **13,** 224–61; 1925.

1231. Keller, B. A. and E. F. Materialien zur ökologischen Anatomie der Gattung *Betula* und *Pinguicula vulgaris* L. Veröff. geobot. Inst. Rübel. **4,** 96–102; 1927. *See* Bot. Zbl., n.s. **12,** 213; 1928.

1232. Keller, B. A., and Leisle, E. F. Vergleichende anatomische und physiologische Untersuchungen einiger ökologischer Eigenheiten von *Asperula* und *Galium*-arten. Westnik. opytn. djela. Woronesh, pp. 16; 1932. *See* Bot. Zbl., n.s. **5,** 201; 1925.

1233. Keller, E. F. Einige anatomische Unterschiede in kochsalzfreien und salzhaltigen Kulturen von *Atriplex veruciferum* M.B. und *A. canum* C. A. Mey. Nat. and Agric. ar. reg. U.R.S.S. Woronesh **1/2,** 77–80; 1927. *See* Bot. Zbl., n.s. **12,** 262; 1928.

1234. Kershaw, E. M. A note on the relationship of the Julianiaceae. Ann. Bot. Lond. **23,** 336–7; 1909.

1235. Keuchenius, P. E. Beitrag zur Anatomie von *Hevea brasiliensis.* Ann. Jard. bot. Buitenz. **29,** 109–11; 1916.

1236. Kienholz, R. An ecological anatomical study of beach vegetation in the Philippines. Proc. Amer. phil. Soc. **65,** Suppl. 58–100; 1926.

1237. Kingsley, M. On the anomalous splitting of the rhizome and root of *Delphinium scaposum.* Bull. Torrey bot. Cl. **38,** 307–17; 1911.

1238. Kisser, J. Histochemische Untersuchung einiger flavon-führenden Farbhölzer. S. B. Akad. Wiss. Wien Math.-Naturw. Kl. **132,** 1. 19–33; 1923.

1239. —— Über eigenartige organische Membraneinschlüsse in der Epidermis von *Portulaca Gilliesii* Hook. Öst. bot. Z. **74,** 115–22; 1925.

1240. —— Die physiologische Abgrenzung der Begriffe 'Exkrete' und 'Sekrete' und die Exkretbildung bei *Plectranthus fruticosus.* Planta, **2,** 489–96; 1926.

1241. —— Das Holz als Werkstoff des Tischlers. Möbel aus heimischen Holz. Vienna, 3–14; 1937.

1242. Kisser, J., and Sekyra, L. W. Die mikroskopische Diagnose heimischer Holzarten in zerkleinertem und pulverisiertem Zustand. Archiv. f. Kriminologie, **103,** 19–32; 1938.

1243. —— Der diagnostische Wert des mikroskopischen Aschenbildes der wichtigsten heimischen Hölzer. Mikrochemie, **25,** 157–68; 1938.

1244. Klebs, G. Alterations in the development and forms of plants as a result of environment. Proc. roy. Soc. Lond. B, **82,** 547–58; 1910.

1245. Klein, G., and Bartosch, H. Der mikrochemische Nachweis der Alkaloide in der Pflanze. V. Der Nachweis von Berberin. Öst. bot. Z. **77,** 1–13; 1928.

1246. Kloimweder, R. Beiträge zur Kenntnis der Schlauchzellen der Fumariaceen. speziell der Gattung *Dicentra.* S. B. Akad. Wiss. Wien Math.-Naturw. Kl. **138,** 517–50; 1929. *See* Bot. Zbl. **17,** 133; 1930.

1247. Klug, J. *Über die Sekretdrüsen bei den Labiaten und Compositen.* Thesis, Frankfurt, pp. 28; 1926. *See* Just's Jber., Pt. 2, 492; 1926.

1248. Knagg, M. M. B. The leaf structure of *Begonia fuchsioides* Hook. Trans. bot. Soc. Edinb. **29,** 63–5; 1927.

1249. Knapheisowna, G. Beiträge zur Verteilung und Anatomie der Sekretionsorgane an den Blättern der *Prunus*-Arten. Acta Soc. Bot. Polon. **4,** 106–13; 1927. *See* Just's Jber., Pt. 1, 960; 1927.

1250. Knight, M. Anatomy of the Magnoliaceae. Ann. Bot. Lond. **29,** 310–11; 1915.

1251. Knuth, R. *Geraniaceae* in Engler's *Das Pflanzenreich,* iv. 129; 1912.

1252. —— Pelargonium oil. Amer. J. Pharm. **93,** 302–15; 1921.

1253. —— *Oxalidaceae* in Engler's *Das Pflanzenreich,* iv. 130; 1930.

1254. KNUTH, R. *Oxalidaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19A; 1931.

1255. —— *Geraniaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19A; 1931.

1256. —— *Asteranthaceae* in Engler's *Das Pflanzenreich*, iv. 219*b*; 1939.

1257. —— *Lecythidaceae* in Engler's *Das Pflanzenreich*, iv. 219*a*; 1939.

1258. —— *Barringtoniaceae* in Engler's *Das Pflanzenreich*, iv. 219; 1939.

1259. KOBUSKI, C. E. Notes on the Mexican and Central American species of *Ternstroemia*. J. Arnold Arbor. **23**, 464–78; 1942.

1260. KOEHLER, A. *Guidebook for the identification of woods used for ties and timbers.* U.S. Dept. Agric., For. Serv., Washington. Misc., pp. 79; 1917.

1261. —— The identification of mahogany. J. For. **28**, 154–6; 1920.

1262. —— *The identification of true mahogany, certain so-called mahoganies and some common substitutes.* Bull. U.S. Dept. Agric., No. 1050, pp. 18; 1922.

1263. —— *The identification of furniture woods.* Misc. Circ. U.S. Dept. Agric., No. 66, pp. 76; 1926.

1264. KOERNICKE, M. Über Rindenwurzeln tropischer Loranthaceen. Naturw. Rundschau, **23**, 552–3; 1908. *See* Just's Jber., Pt. 1, 464; 1908.

1265. —— Über die extrafloralen Nektarien auf den Laubblättern einiger Hibisceen. Flora, Jena, Festschr. Stahl. **111/12**, 526–40; 1918.

1266. KONNERTH, R. A., and PICKERING, E. *Digitalis lutea* and *D. purpurea*. J. Amer. pharm. Ass. **15**, 1069–71; 1926.

1267. KONSTANTY, E. C. Über die Entstehung der Kristallzellenreihen mit besonderer Berücksichtigung der Drogenpflanzen. Bot. Arch. **15**, 131–5; 1926.

1268. KORN, B. *Untersuchungen über die technisch-mikroskopische Unterscheidung einiger Fasern, insbesondere der Leinen- und Hanffaser.* Thesis, Dresden, pp. 46; 1910. *See* Just's Jber., Pt. 2, 1605; 1910.

1269. KOSTERMANS, A. J. G. H. Review of Lauraceae V. Rec. Trav. bot. néerland. **35**, 834–931; 1938.

1270. KOSTYTSCHEW, S. La structure et l'accroisement en épaisseur de la tige des Dicotylédones. Zh. russk. bot. Absch. **5**, Supplement 1–57; (1920) 1921. Russian with French summary. *See* Just's Jber., Pt. 2, 91; 1921.

1271. —— Der Bau und das Dickenwachstum der Dikotylenstämme. Ber. dtsch. bot. Ges. **40**, 297–305; 1922.

1272. —— Der Bau und das Dickenwachstum der Dikotylenstämme. Beih. bot. Zbl. **40**, 1. 295–350; 1923/4.

1273. KRAEMER, H. The histology of the rhizome and roots of *Phlox ovata* L. (*Phlox carolina* L.). Amer. J. Pharm. **82**, 470–5; 1910.

1274. —— *Digitalis*, Variation in the form of hairs of. Amer. J. Pharm. **84**, 35; 1912.

1275. KRAMER, P. R. The woods of *Billia*, *Cashalia*, *Henoonia* and *Juliania*. Trop. Woods, **58**, 1–5; 1939.

1276. KRÄNZLIN, Fr. *Scrophulariaceae-Antirrhinoideae-Calceolarieae* in Engler's *Das Pflanzenreich*, iv. 257*c*; 1908.

1277. KRATZMANN, E. Über den Bau und die vermutliche Funktion der 'Zwischenwanddrüsen' von *Rhododendron hirsutum*, *intermedium* und *ferrugineum*. Öst. bot. Z. **60**, 409–24; 1910.

1278. KRAUSE, K. *Goodeniaceae und Brunoniaceae* in Engler's *Das Pflanzenreich*, iv. 277 & 277*a*; 1912.

1278A. —— *Lacistemaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, **21**, 321–2; 1925.

1279. KRAUS, E. J., and MITCHELL, J. W. Histological and physiological responses of bean plants to α-naphthalene acetamide. Bot. Gaz. **101**, 1. 204–25; 1939.

1280. KREMER, E. Beiträge zur Kenntnis des Winterleins. Faserforschung, **3**, 181–217; 1923. *See* Just's Jber., Pt. 1, 673; 1923.

1281. Kreusch, W. Über Entwicklungsgeschichte und Vorkommen des Kalziumoxalates in Solanaceen. Beih. bot. Zbl. **50,** 410–31; 1933.

1282. Kribs, D. A. Comparative anatomy of the woods of the Juglandaceae. Trop. Woods, **12,** 16–21; 1927.

1283. —— The Persaud collection of British Guiana woods. Trop. Woods, **13,** 7–46; 1928.

1284. —— The wood of *Carya tonkinensis* H. Lecomte. Trop. Woods, **16,** 50–2; 1928.

1285. —— Comparative anatomy of the woods of the Meliaceae. Ann. Bot. Lond. **17,** 724–38; 1930.

1286. —— Salient lines of structural specialization in the wood rays of dicotyledons. Bot. Gaz. **96,** 547–57; 1935.

1287. —— Salient lines of structural specialization in the wood parenchyma of dicotyledons. Bull. Torrey bot. Cl. **64,** 177–86; 1937.

1288. Krüger, L. Ein Beitrag zur Biologie von *Chenopodium album.* Bedeutung und Bekämpfung als landwirtschaftliches Unkraut. Angew. Bot. **13,** 1. 1–49; 1931.

1289. Krukoff, B. A. Supplementary notes on the American species of *Erythrina.* Amer. J. Bot. **28,** 683–91; 1941.

1290. Krukoff, B. A., and Smith, A. C. Rotenone-yielding plants of South America. Amer. J. Bot. **24,** 573–87; 1937.

1291. Kudelka, W. Die Pfefferminze (*Mentha piperita*). Botanisches Studium. Kosmos, Lemberg, **51,** 139–76; 1926 (1927). *See* Just's Jber., Pt. 2, 446; 1926.

1292. Kugler, H. Über invers-dorsiventrale Blätter. Planta, **5,** 89–139; 1928.

1293. Kuhl, R. Vergleichend-entwicklungsgeschichtliche Untersuchungen an der Insectivore *Nepenthes.* Beih. bot. Zbl. **51,** Abt. 1, 311–34; 1933.

1294. Kuhlmann, J. G. Notas sôbra o género *Duckeodendron.* Arch. Instit. Bio. Vegetal. **1,** 35–7; 1934.

1295. Kukachka, B. F., and Rees, L. W. Systematic anatomy of the woods of the Tiliaceae. Tech. Bull. Minn. agric. Exp. Sta. **158,** 1–70; 1943.

1296. Kumazawa, M. Structure and affinities of *Glaucidium* and its allied genera. Bot. Mag. Tokyo, **44,** 479–90; 1930.

1297. —— Studies on the structure of Japanese species of *Ranunculus.* J. Fac. Sci. Tokyo Univ. **2,** 3. 297–343; 1930.

1298. —— Morphology and biology of *Glaucidium palmatum* Sieb. et Zucc. with notes on affinities to the allied genera *Hydrastis*, *Podophyllum* and *Diphylleia.* J. Fac. Sci. Tokyo Univ. **2,** 4. 345–80; 1930.

1299. —— The medullary bundle system in the Ranunculaceae and allied plants. (English summary.) Bot. Mag. Tokyo, **46,** 327–32; 1932.

1300. —— Morphological studies of *Anemonopsis, Actaea* and *Cimicifuga.* J. Fac. Sci. Tokyo Univ. **2,** 6. 413–54; 1932.

1301. Kummer, F. *Beiträge zur Anatomie und Systematik der Rhipsalideen.* Thesis, Tübingen, pp. 55; 1918. *See* Just's Jber., Pt. 2, 75; 1921.

1302. Kundu, B. C. The anatomy of two Indian fibre plants, *Cannabis* and *Corchorus*, with special reference to fibre distribution and development. J. Indian bot. Soc. **21,** 93–128; 1942.

1303. —— The morphology of the spines of *Hygrophila spinosa* T. Anders. J. Bombay nat. Hist. Soc. **43,** 678–80; 1943.

1304. Kundu, B. C., and Preston, R. D. The fine structure of phloem fibres. I. Untreated and swollen hemp. Proc. Roy. Soc. B, **128,** 214–31; 1940.

1305. Kunz, M. *Systematisch-anatomische Untersuchung der Verbenoideae unter Ausschluss der Gattungen Verbena, Lantana, Lippia.* Thesis, Erlangen, pp. 78; 1911.

1306. —— Die systematische Stellung der Gattung *Krameria* unter besonderer Berücksichtigung der Anatomie. Beih. bot. Zbl. **30,** 2. 412–27; 1913.

1307. KURER, G. A. *Kutikularfalten und Protuberanzen an Haaren und Epidermen und ihre Verwendung zur Differenzialdiagnose offizineller Blätter.* Thesis, Zürich, pp. 107; 1917.

1308. KURT, J. Über die Hydathoden der Saxifrageae. Beih. bot. Zbl. **46,** I. 203–46; 1929.

1309. KURZ, I. Beiträge zur Frage nach dem Einfluss mechanischen Druckes auf Entstehung und Zusammensetzung des Holzes. Zbl. Bakt. **2,** 55. 293–8; 1922.

1310. KUSTER, E. Über rhythmisches Dickenwachstum. Flora, Jena, **111–12** (Festschr. Stahl.), 621–40; 1918.

1311. LACOSTE, A. Notes générales sur l'étude anatomique des espèces Malgaches du genre *Crotalaria.* Rev. gén. Bot. **27,** 10–21; 1915.

1312. —— *Étude anatomique sur les Papilionacées de Madagascar.* Thesis, Paris, pp. 161; 1915.

1313. LAKON, G. Über die 'Krypten' der *Coprosma*-Blätter. Zbl. Bakt. II. **53,** 1–6; 1921. *See* Just's Jber., Pt. 2, 75; 1921.

1314. LAM, H. J. On the system of the Sapotaceae with some remarks on taxonomical methods. Rec. Trav. bot. néerland. **36,** 509–25; 1939.

1315. LAMBETH, E. C. Ontogeny of medullary bundles in *Apium graveolens.* Bot. Gaz. **102,** 400–5; 1940.

1316. LAMORLETTE, S. *Remarques sur la tige et la feuille des Nerpruns.* Thesis, Paris, 1908. *See* Just's Jber., Pt. 1, 995; 1909.

1317. LANGDON, L. D. M. The ray system of *Quercus alba.* Bot. Gaz. **65,** 313–23; 1918.

1318. —— Development and vascular organisation of the foliar organs of *Carya cordiformis.* Bot. Gaz. **91,** 277–94; 1931.

1319. LANGE, F. Vergleichende Untersuchungen über die Blattentwicklung einiger *Solanum*-chimären und ihre Elterarten. Planta, **3,** 181–281; 1927.

1320. LA RIVIÈRE, H. C. C. L'épaissement des tiges du *Vitis lanceolaria* Wall. Ann. Jard. bot. Buitenz. **31,** 141–66; 1921.

1321. LASHEVSKI, W. On the liane structure in the subterranean stem of *Daphne Julia* K. Pol. Bull. Soc. Nat. Voronèje, **1,** 29–36; 1925 (1926). *See* Just's Jber., Pt. 2, 447; 1926.

1322. LAVIER-GEORGE, L. Les épidermes foliaires de *Rhododendron Williamsianum* Rehd. and Wils., *Rhododendron orbiculare* Decne. et leur hybride (*R. Williamsianum* × *R. orbiculare*). Bull. Soc. bot. Fr. **83,** 809–16; 1936.

1323. LEACH, W. An anatomical and physiological study of the petiole in certain species of *Populus.* New Phytol. **33,** 225–39; 1934.

1324. LÉANDRI, J. Structure particulière du rhizom d'un *Daphne.* Bull. Soc. bot. Fr. **75,** 243–8; 1928.

1325. —— Recherches anatomiques sur les Thymeleacées. Ann. Sci. nat. b., Ser. 10, **12,** 125–237; 1930.

1326. —— Observations sur les rhizomes à structure anormale de quelques espèces africaines de *Gnidia.* Bull. Soc. bot. Fr. **78,** 307–12; 1931.

1327. —— Les 'Croton' de Madagascar et des îles voisines. Ann. Mus. colon. Marseille, **47,** I. 1–88; 1939.

1328. LECHNER, S. Anatomische Untersuchungen über die Gattungen *Actinidia, Saurauia, Clethra* und *Clematoclethra* mit besonderer Berücksichtigung ihrer Stellung im System. Beih. bot. Zbl. **32,** I. 431–67; 1914.

1329. LECOMTE, H. Sur les principaux caractères de structure du bois. Bull. Mus. Hist. nat. Paris, **26,** 166–71; 1920.

1330. —— Sur la 'structure étagée' de certains bois. C. R. Acad. Sci. Paris, **170,** 705–9; 1920.

1331. —— Une Juglandacée du genre *Carya* en Indo-chine. Bull. Mus. Hist. nat. Paris, **27,** 437–40; 1921.

1332. LECOMTE, H. *Les bois de la forêt d'Analamazaotra.* Paris, pp. 189; 1922.

1333. —— *Les bois coloniaux.* Paris, pp. 194; 1923.

1334. —— *Les bois de l'Indochine.* Paris, pp. 311; 1925.

1335. —— Une Ochnacée nouvelle d'Indochine. Bull. Mus. Hist. nat. Paris, **32,** 95–100; 1926.

1336. LEDOUX, P. Sur les caractères histologiques du cylindre-axe caulinaire chez *Entandrophragma Leplaei* Verm. et *E. roburoides* Verm. Bull. Acad. roy. Belg. Cl., Sér. 5, **13,** 807–11; 1927.

—— Contributions à la Drymologie du Congo.

1337. I. Sur l'*Entandrophragma Delevoyi* de Willd. (Meliaceae) et l'appareil végétatif jeune d'une Meliacée du Katanga. Bull. Soc. for. Belg. **31,** 202–4; 1928.

1338. II. Nouvelles recherches histologiques sur des *Entandrophragma* C. DC. (Meliaceae) du Congo Belge. Bull. Soc. for. Belg. 2–7; 1929. *See* Bot. Zbl., N.S. **17,** 261; 1930.

1339. LEE, D. G. Notes on the anatomy and morphology of *Pachypodium namaquanum* Welw. Ann. Bot. Lond. **26,** 929–42; 1912.

1340. LEEMANN, A. Contribution à l'étude de l'*Asarum europaeum* L. avec une étude particulière sur le développement des cellules sécrétices. Bull. Soc. bot. Genève, **19,** 92–173; 1927.

1341. —— Das Problem der Sekretzellen. Planta, **6,** 216–33; 1928.

1342. LEGAULT, A. Recherches anatomiques sur l'appareil végétatif des Geraniacées. C. R. Acad. Sci. Paris, **147,** 382–4; 1908. *See* Just's Jber., Pt. 1, 466; 1908.

1343. LEHMANN, C. Studien über den Bau und die Entwicklungsgeschichte von Ölzellen. Planta, **1,** 343–73; 1925.

1344. —— Untersuchungen über die Anatomie der Kartoffelknolle, unter besonderer Berücksichtigung des Dickenwachstums und der Zellgrösse. Planta, **2,** 87–131; 1926.

1345. LEINFELLNER, W. Beiträge zur Kenntnis der Cactaceen-Areolen. Öst. bot. Z. **86,** 1–60; 1937.

1346. LEMESLE, R. Contribution à l'étude structurale des Ombellifères xérophiles. Ann. Sci. nat. b., Sér. 10, **8,** 1–138; 1926.

1347. —— Sur l'existence d'un rhytidome chez certaines Labiées. Bull. Soc. bot. Fr. **73,** 983–6; 1926.

1348. —— De l'existence d'une liège intraligneux chez une Labiée (*Hymenocrater bituminosus* Fisch. et Mey.). Bull. Soc. bot. Fr. **74,** 904–7; 1927.

1349. —— Contribution à l'étude structurale de quelques Labiées extra-européennes. Bull. Soc. bot. Fr. **75,** 18–25; 1928.

1350. —— Formations subéreuses anormales chez une Labiée. C. R. Acad. Sci. Paris, **186,** 455–7; 1928.

1351. —— De l'ancienneté des caractères anatomiques des Magnoliacées. Rev. gén. Bot. **45,** 341–55; 1933.

1352. —— Étude anatomique du genre *Calligonum* L. Ann. Sci. nat. b., Ser. 10, **16,** 1–62; 1934.

1353. —— Les vaisseaux à perforations scalariformes de l'*Eupomatia* et leur importance dans la phylogénie des Polycarpes. C. R. Acad. Sci. Paris, **203,** 1538–40; 1936.

1354. —— Étude microchemique des divers tannoides de l'*Eupomatia.* Bull. Soc. bot. Fr. **84,** 7/8. 535–8; 1937.

1355. —— Les trachéides à ponctuations aréolées de *Sargentodoxa cuneata* Rehd. et Wils. et leur importance dans la phylogénie des Sargentodoxacées. Bull. Soc. bot. Fr. **90,** 104–7; 1943.

1356. —— La constitution anatomique du bois secondaire chez les Ipecacuanhas vrais. Rev. gén. bot. **54,** 138–51; 1947.

1357. LENDNER, A. Contribución al estudio de las falsificaciones de la Yerba mate.

Trab. Inst. Bot. Farmacol. B. Aires, **35**, pp. 55; 1917. *See* Bot. Jb. **56**, Lit.-Ber. 31; 1920/21.

1358. LENDNER, A. L'anatomie du *Solenostemma Arghel* Hayne. Schweiz. ApothZtg. **62**, Sonderbeil., 9–13; 1924. *See* Just's Jber. 326; 1924.

1359. LEON, H. La guana y su aprovechamiento. Mem. Soc. cubana Hist. nat. **8**, 63–8; 1934.

1360. LEONHARDT, H., and FAY, K. Zur Kenntnis der Inhaltstoffe des roten Sandelholzes. Pterokarpin. Arch. Pharm. Berl. **273**, 53–60; 1935.

1361. LEPESCHKIN, W. Recherches sur les organes du bord des jeunes feuilles. Bull. Soc. bot. Genève, Sér. 2, **13**, 226–35; 1921.

1362. LE RENARD, A. Recherches anatomiques sur la tige et la feuille des Sabiacées. J. Bot. **21**, 290–332; 1908. *See* Just's Jber., Pt. 1, 467; 1908.

1363. —— Rapports anatomiques du genre *Arfeuillea*. Ann. Sci. nat. b., Sér. 9, **17**, 353–89; 1913.

1364. LEUPIN, K. O. *Beiträge zur Anatomie des Laubblattes pharmazeutisch interessanter Papilionatae*. Thesis, Basel, pp. 84; 1932.

1365. LEVEILLE, H. *Monographie du genre Oenothera avec la collaboration pour la partie anatomique de Guffroy Ch.* Le Mans, pp. 466; 1912–13. *See* Just's Jber., Pt. 2, 1083; 1913.

1366. LEVIN, F. A. The taxonomic value of vein islet areas based upon a study of the genera *Barosma*, *Cassia*, *Erythroxylon*, and *Digitalis*. Quart. J. Pharm. **2**, 17–43; 1929.

1367. LEWINSKY, E. Vergleichende Anatomie der Wurzeln und Rhizome einiger pharmakognostich wichtiger Solanaceen. Lokalisation und Bestimmung der Alkaloide. Bot. Arch. **6**, 313–33; 1924.

1368. LIEBAU, O. Beiträge zur Anatomie und Morphologie der Mangrove-Pflanzen, insbesondere ihres Wurzelsystems. Beitr. Biol. Pfl. **12**, 182–213; 1913.

1369. LIEBTAG, C., and MCDOUGALL, W. B. Ecologic foliar anatomy of some plants common to Illinois and North Carolina. Trans. Ill. Stat. Acad. Sci. **21**, 77–83; 1929.

1370. LIERMANN, K. *Beiträge zur vergleichenden Anatomie der Wurzeln einiger pharmazeutisch verwendeter Umbelliferen*. Thesis, Basel, pp. 98; 1926. *See* Just's Jber., Pt. 2, 448; 1926.

1371. LIEVRE, L. Sur un nouvel hybride de *Micromeria*. Bull. Soc. Hist. nat. Afr. N. **12**, 172–8; 1921.

1372. LI HUI-LIN. On the Sino-Himalayan species of *Shortia* and *Berneuxia*. Rhodora, **45**, 333–7; 1943.

1373. LINDEMUTH, K. Beiträge zur Biologie von *Vicia hirsuta* Koch. und ihre Bedeutung als landwirtschaftliches Unkraut. Bot. Arch. **7**, 195–251; 1924.

1374. LINDINGER, L. Vorläufige Mitteilung über einige Ergebnisse meiner zweiten Kanarenreise. Bot. Arch. **4**, 263–77; 1923.

1375. LINDSEY, A. A. Anatomical evidence for the Menyanthaceae. Amer. J. Bot. **25**, 480–5; 1938.

1376. LINGELSHEIM, A. *Oleaceae* in Engler's *Das Pflanzenreich*, iv. 243 I and II; 1920.

1377. LINK, A. Über Ringbildung bei einigen Tropenhölzern. Verh. naturh.-med. Ver. Heidelberg. **13**, 355–94; 1916.

1378. LINSBAUER, K. Über die kalkfreien Cystolithen der Acanthaceen. Ber. dtsch. bot. Ges. **39**, 41–9; 1921.

1379. LITTLE, E. L. *Ochroma lagopus* Swartz., the name of the balsa of Ecuador. Carribean Forester, **5**, 108–13; 1944.

1380. LITTLE, RUBY R. *Histology of barks of Cinchona and some related genera occurring in Colombia*. Revista de la Academia Colombiana **7**, 404–25; 1947.

1381. LLOYD, F. E. *Guayule* (*Parthenium argentatum* Gray), *a rubber plant of the Chihuahuan desert*. Carnegie Inst. Wash. Publ. 139, pp. 213; 1911.

1382. —— The cytology of vegetable crystals. Science, **57**, 273–4; 1923.

1383. Lloyd, F. E. *The carnivorous plants.* Waltham, Mass., pp. 352; 1942.

1384. Lloyd, F. E., and Ridgway, C. S. The behaviour of the nectar gland in the Cacti with a note on the development of the trichomes and areolar cork. Plant World, **15,** 145–56; 1912. *See* Bot. Zbl. **125,** 290; 1914.

1385. Lodewick, J. E. Growth studies in forest trees. III. Experiments with the dendrograph on *Fraxinus americana.* Bot. Gaz. **79,** 3. 311–23; 1925.

1386. —— *Seasonal activity of the cambium in some Northeastern trees.* Tech. Publ. N.Y. St. Coll. For., No. 23, pp. 82; 1928.

1387. Lodewick, J. E., and Harrar, E. S. What wood is that? Timberman, **38,** 9, 18–24; 1937.

1388. Loeffler, B. Entwicklungsgeschichtliche und vergleichendanatomische Untersuchungen des Stammes und der Uhrfederanken von *Bauhinia* (*Phaneria*) sp., ein Beitrag zur Kenntnis der rankenden Lianen. S. B. Akad. Wiss. Wien Math.-Naturw. Kl. **51,** 174; 1914.

1389. Loesner, Th. *Celastraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 5; 1892.

1390. —— *Hippocrateaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 5; 1896.

1391. Losch, H. *Beiträge zur vergleichenden Anatomie der Urticineenwurzeln mit Rücksicht auf die Systematik.* Thesis, Göttingen, pp. 100; 1913.

Louis, J., and Foarge, J. Essences forestières et bois du Congo:

1392. 1. *Afrormosia elata.* Publ. Inst. Nat. l'Étude Agron. Congo Belge (Brussels), No. 2, pp. 22; 1943.

1393. 2. *Guarea thompsonii.* Publ. Inst. Nat. l'Étude Agron. Congo Belge (Brussels), No. 3, pp. 38; 1944.

1394. Lourteig, A. Lythraceae argentinae. Lilloa, **9,** 318–421; 1943.

1395. Lourteig, A., and O'Donnell, C. A. Euphorbiaceae argentinae: Phyllantheae, Dalechampieae, Cluytieae, Manihoteae. Lilloa, **9,** 77–173; 1943.

1396. Lovejoy, B. *Gaertneria deltoidea* Torr. Kans. Univ. Sci. Bull. **7,** 277–88; 1913. *See* Just's Jber., Pt. 2, 1117; 1913.

1397. Löw, K. Über Unterschiede in der Anatomie von Zweigen der Trauerbäume und der entsprechenden aufrechten Formen. Ber. dtsch. bot. Ges. **35,** 104–19; 1917.

1398. Lubenau, G. Die Kalziumoxalatkristalle der Solanaceen. Was bedingt das Auftreten der einzelnen Kristallformen? Beih. bot. Zbl. **53,** 1. 439–500; 1935.

1399. Luckan, L. Ecological morphology of *Abutilon theophrasti.* Kans. Univ. Sci. Bull. **10,** 219–28; 1917. *See* Just's Jber., Pt. 1, 263; 1920.

1400. Luckwill, L. C. *The genus Lycopersicon.* Aberdeen Univ. Studies, No. 120; 1943.

1401. Lunan, M. Anatomical investigations on *Ligusticum scoticum.* Trans. bot. Soc. Edinb. **32,** 353–63; 1937.

1402. Lupton, A. W. The determination of stem in Ipecacuanha. Quart. J. Pharm. **11,** 2. 225; 1938.

1403. Luthra, J. C., and Sharma, M. M. L. Some studies on the conductivity and histology of grafted Mango shoots. J. Indian bot. Soc. **25,** 221–9; 1946.

1404. Lutz, A. *Beiträge zur Pharmakognosie der Salicales Juglandales und Fagales. Anatomie des Laubblattes.* Thesis, Basel, pp. 84; 1938.

1405. Maas, E. Die Entwicklung des Stammaufbaues einiger *Crassula*-Arten. Beih. bot. Zbl. **48,** 1. 118–54; 1931.

1406. Maby, J. C. Sandalwood and its substitutes. Analyst, **57,** 515; 1932.

1407. MacDaniels, L. H., and Cowart, F. F. The development and structure of the apple leaf. Mem. Cornell Univ. Agric. Exp. Sta. **258,** 1–29; 1944.

1408. MacDuffie, R. C. Vessels of the Gnetalean type in angiosperms. Bot. Gaz. **71,** 438–45; 1921.

1409. MACFARLANE, J. M. *Sarraceniaceae* in Engler's *Das Pflanzenreich*, iv. 110; 1908.

1410. —— *Nepenthaceae* in Engler's *Das Pflanzenreich*, iv. 111; 1908.

1411. —— *Cephalotaceae* in Engler's *Das Pflanzenreich*, iv. 116; 1911.

1412. MACKLIN, E. D. A revision of the 'distyla complex' of the genus *Casuarina*. Trans. roy. Soc. S. Austr. **51,** 257–86; 1927.

1413. MAEDER, R. *Pharmakochemische und physiologische Untersuchung der Cortex Frangulae.* Thesis, St. Gallen, pp. 81; 1925.

1414. MAGITT, M. and E. Studien über die Anatomie des Baumwollstrauches II. Das palisaden Parenchym im Blatt des Baumwollstrauches. J. Soc. bot. Russie, **14,** 191–8; 1929. *See* Bot. Zbl., N.S. **17,** 323; 1930.

1415. MAHESHWARI, P. Origin and development of internal bundles in the stem of *Rumex crispus*. J. Indian bot. Soc. **8,** 89–117; 1929.

1416. —— Contribution to the morphology of *Boerhaavia diffusa*. J. Indian bot. Soc. **9,** 42–61; 1930.

1417. MAHESHWARI, P., and BALWANT SINGH. On the internal bundles in the stem of *Rumex patientia* L. Proc. Indian Acad. Sci. **45,** 153–7; 1942.

1418. MAHEU, J., and CHARTIER, J. Faux Ipéca et origine botanique de l'Ipéca strié mineur *Manettia ignita* Schum. Bull. Sci. Pharm. **34,** 347–57; 1927.

1419. MAIRE, R. Un nouveau *Convolvulus* algérien. Bull. Soc. bot. Fr. **60,** 253–6; 1913.

1420. MAJUMDAR, G. P. Hetero-archic roots in *Enhydra fluctuans* Lour. J. Indian bot. Soc. **11,** 225–7; 1932.

1421. —— On the occurrence of multiperforate plates in the xylem vessels of *Heracleum sphondylium* L. Proc. Leeds phil. lit. Soc. **3,** 559–64; 1939.

1422. —— The sliding, gliding, symplastic or intrusive growths of the cambium cells and their derivatives in higher vascular plants. J. Indian bot. Soc. **20,** 161–71; 1941.

1423. —— Anomalous structure of the stem of *Nyctanthes arbortristis* L. J. Indian bot. Soc. **20,** 119–22; 1941.

1424. —— The organisation of the shoot in *Heracleum* in the light of development. Ann. Bot. Lond., N.S. **6,** 49–80; 1942.

1425. —— The origin and nature of the bases of the secondary thickening of xylem vessels in *Heracleum sphondylium*. Current Sci. **10,** 82–3; 1941. *See* Biol. Abstr. **16,** 2417; 1942.

1426. —— *Some aspects of anatomy in modern research.* Pres. Address, Indian Sci. Congress, Nagpur, pp. 15; 1945.

1427. —— Growth unit or the phyton in dicotyledons with special reference to *Heracleum*. Bull. Bot. Soc. Bengal, 61–6; 1947.

1428. MAJUMDAR, G. P., and PRESTON, R. D. The fine structure of collenchyma cells in *Heracleum sphondylium* L. Proc. roy. Soc. Lond. B, **130,** 201–17; 1941.

1429. MALCUIT, G., and DAVID, R. Contribution à l'étude du genre *Plectaneia*. L'anatomie foliaire du *Plectaneia rhomboidialis* Jum. et Perr. Bull. Mus. Hist. Nat. Marseille, **2,** 55–63; 1942. *See* Biol. Abstr. **20,** No. 18270; 1946.

1430. MALHOTRA, RAM C. A contribution to the physiology and anatomy of tracheae with special reference to fruit trees. I. Influence of tracheae and leaves on the water conductivity. Ann. Bot. Lond. **45,** 593–619; 1931.

1431. MANGANARO, A. Caracteres histológicos genéricos y específicos de las Leguminosas bonaerenses, extrabonaerenses y exóticos. Rev. Mus. La Plata, **27,** 221–56; 1923. *See* Bot. Zbl., N.S. **6,** 44; 1925.

1432. MANNING, W. E. The morphology of the flowers of the Juglandaceae. I. The inflorescence. Amer. J. Bot. **25,** 407–19; 1938 (*a*).

1433. MANSFIELD, R. Vorarbeiten zu einer Monographie der Gattung *Ligustrum*. Bot. Jb. Beibl. **59,** 132. 19 75; 1924. *See* Just's Jber., Pt. 2, 450; 1926.

1434. MANSFIELD, W. *Histology of medicinal plants.* New York, pp. 305; 1916.

1435. Manteuffel, A. Untersuchungen über den Bau und Verlauf der Leitbündel in *Cucurbita Pepo*. Beih. bot. Zbl. **43,** 1. 153–66; 1926.

1436. Mao, T. L. *Étude comparative des caractères anatomiques et du parcours des faisceaux libéro-ligneux des Chenopodiacées et des Amarantacées*. Thesis, Paris, pp. 342; 1933.

1437. Maplethorpe, C. W. The structure and development of the bark of *Erythrophloeum guineense* G. Don. Pharm. J. **113,** 106–8; 1924.

1438. Marco, H. F. The wood of *Sarcosperma paniculatum*. Trop. Woods, **33,** 1–4; 1933.

1439. —— Systematic anatomy of the woods of the Rhizophoraceae. Trop. Woods, **44,** 1–20; 1935.

1440. Mariani, J. *Les Cafiers. Structure anatomique de la feuille*. Lons-le Saunier, L. Declume, pp. 140; 1908. *See* Just's Jber., Pt. 1, 472; 1908.

1441. Markgraf, F. Die Organe der Sukkulenten. Mschr. Kakteenk. **32,** 23–6, 41–3, 82–6, 125–7, 133–41; 1922.

1442. —— Die Gattung *Astronidium* A. Gray. Notizbl. Bot. Gart. Berlin-Dahlem, **12,** 47–50; 1934.

1443. Marlier-Spirlet, M. L. Sur quelques épidermes des feuilles de *Cinnamomum* L. Bull. Jard. bot. Bruxelles, **17,** 266–305; 1945.

1444. Marloth, R. Die Schutzmittel der Pflanzen gegen übermässige Insolation. Ber. dtsch. bot. Ges. **27,** 362–71; 1909.

1445. —— Notes on the absorption of water by aerial organs of plants. Trans. roy. Soc. S. Afr. **1,** 429–33; 1910.

1446. Marroquin, A. S., and Howard, A. W. Un estudio morfológico de la plantula de *Claytonia virginica* L. An. Escuela Nacion. Cienc. Biol. México, **2,** 191–215; 1940. *See* Biol. Abstr. **16,** No. 18827; 1942.

1447. Marsden-Jones, E. M., and Turrill, W. B. Reports on the transplant experiments of the British Ecological Society at Potterne, Wilts.:

1. J. Ecol. **18,** 352–78; 1930.
2. J. Ecol. **21,** 268–93; 1933.
3. J. Ecol. **23,** 443–69; 1935.
4. J. Ecol. **25,** 189–212; 1937.
5. J. Ecol. **26,** 359–79; 1938.

Summary of results 1928–37. J. Ecol. **26,** 380–9; 1938.

1448. Martens, P. Différenciation épidermique et cuticulaire chez *Erythraea centaurium*. Ann. Sci. nat. b. **17,** 5–32; 1935.

1449. Martin-Lavigne, E. Sur une curieuse formation de thylles dans le bois d'une Artocarpée. J. Botanique, **21,** 281–6; 1908.

1450. —— Recherches sur les bois de la Guyane: Leur identification à l'aide des caractères extérieurs et microscopiques. Trav. Lab. Mat. méd. **6,** 1–181; 1910.

1451. Marvin, J. W. Cell shape studies in the pith of *Eupatorium purpureum*. Amer. J. Bot. **26,** 487–504; 1939.

1452. —— Cell shape and cell volume in the pith of *Eupatorium perfoliatum*. Amer. J. Bot. **31,** 208–18; 1944.

1453. Masao, M. On the difference of wood tissue and quantity of tannins in certain varieties of *Diospyros kaki* and *D. Lotus*. Bull. Miyazaki Coll. Agric. For. **4,** 69–86; 1932.

1454. Mashtakov, S. M. Qualitative variations of rubber in the roots of kok-saghyz at the second year of vegetation. C. R. Acad. Sci. U.R.S.S. **24,** 5. 509–12; 1939.

1455. Matern, F. Gleitendes Wachstum. Naturforscher, **3,** 243–5 and 650–3; 1926.

1456. Mathiesen, Fr. J. Beiträge zur Kenntnis der Podostemonaceen. Bibliotheca bot. **68,** 1–55; 1908.

1457. —— The structure and biology of Arctic flowering plants. II. Primulaceae. Meddel. om Grønland, **37,** 167–220; 1915. *See* Just's Jber., Pt. 1, 516; 1915.

1458. Mathiesen, Fr. J. XV. Scrophulariaceae. Meddel. om Grønland, **37,** 361–507; 1921.

1459. Matthews, J. R. Floral morphology and its bearing on the classification of angiosperms. Proc. bot. Soc. Edinb. **33,** 69–82; 1941.

1460. Maue, G. *Zur Pharmakognosie der Ranunculaceen und Berberidaceen. Anatomie des Laubblattes.* Thesis, Kiel, pp. 160; 1926.

1461. Maximov, N. A. *The plant in relation to water.* English translation by R. H. Yapp, London, pp. 451; 1929.

1462. Mayer-Alberti, M. Vergleichende Untersuchungen über den Blattbau einiger *Solanum*-Pfropfbastarde. Mitt. Inst. allg. Bot. Hamburg, **6,** 1–32; 1924. *See* Just's Jber., 343; 1924.

1463. McCormick, F. A. Notes on the anatomy of the young tuber of *Ipomoea batatas* Lam. Bot. Gaz. **61,** 388–98; 1916.

1464. McCown, M. Anatomical and chemical aspects of abscission of fruits of the apple. Bot. Gaz. **105,** 212–20; 1943.

1465. McIntyre, W. G., and Chrysler, M. A. The morphological nature of the photosynthetic organs of *Archyllium endresii,* as indicated by their vascular structure. Bull. Torrey bot. Cl. **70,** 252–60; 1943.

1466. McLaughlin, R. P. Some woods of the Magnolia family. J. For. **26,** 665–77; 1928.

1467. —— Systematic anatomy of the woods of the Magnoliales. Trop. Woods, **34,** 3–37; 1933.

1468. McLean, F. T. A study of the structure of the stomata of two species of *Citrus* in relation to citrus canker. Bull. Torrey bot. Cl. **48,** 101–6; 1921.

1469. McLeod, A. M. The significance of the distribution of stomata on the leaves of the genus *Primula.* Trans. bot. Soc. Edinb. **33,** 12–20; 1939.

1470. McLuckie, J. Studies in symbiosis, 10. The root nodules of *Casuarina cunninghamiana* and their physiological significance. Proc. Linn. Soc. N.S.W. **48,** 194–205; 1923.

1471. —— Studies in parasitism. A contribution to the physiology of the Loranthaceae of N. S. Wales. Bot. Gaz. **75,** 333–69; 1923.

1472. McNair, G. T. Comparative anatomy within the genus *Euonymus.* Kans. Univ. Sci. Bull. **19,** 221–72; 1930.

1473. McNair, J. B. Secretory canals of *Rhus diversiloba* T. & G. Bot. Gaz. **65,** 268–73; 1918.

1474. —— The morphology and anatomy of *Rhus diversiloba* T. & G. Amer. J. Bot. **8,** 179–91; 1921.

1475. —— Angiosperm phylogeny on a chemical basis. Bull. Torrey bot. Cl. **62,** 515–32; 1935.

1476. —— Some chemical properties of *Eucalyptus* in relation to their evolutionary status. Madroña, S. Francisco, **6,** 181–90; 1942.

1477. —— Hydrophytes, xerophytes and halophytes and the production of alkaloids, cyanogenetic and organic sulphur compounds. Lloydia, **6,** 1–17; 1943.

1478. —— Advance in phylogenetic position in the cryptogams as indicated by their fats. Lloydia, **6,** 155–6; 1943.

1479. Mehrlich, F. B. Factors affecting growth from the foliar meristems of *Bryophyllum calycinum.* Bot. Gaz. **92,** 113–40; 1931.

1480. Melchior, H. Über den anatomischen Bau der Saugorgane von *Viscum album* L. Beitr. allg. Bot. **2,** 55–86; 1921. *See* Bot. Zbl., n.s. **2,** 163; 1922/3.

1481. —— *Theaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.,* Auf. 2, 21; 1925.

1482. —— Über das Vorkommen von Inulin in den Blättern der Marcgraviaceen. Ber. dtsch. bot. Ges. **42,** 198–204; 1924.

1483. —— *Violaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.,* Auf. 2, 21; 1925.

1484. Mell, C. D. History of the investigations of vessels in wood. Proc. Soc. Amer. For. **6,** 78–91; 1911.

1485. MELL, C. D. True mahogany. Bull. U.S. Dep. Agric. **474**, pp. 24; 1917.

1486. MELL, C. D., and BRUSH, W. D. Quebracho wood and its substitutes. Circ. U.S. Div. For. Serv. **202**, pp. 12; 1912.

1487. —— Greenheart. Circ. U.S. Div. For. Serv. **211**, pp. 12; 1913.

1488. MELNIKOV, A. N. A contribution to the comparative anatomy of the stem of Russian flax. Bull. appld. Bot. Select. **17**, 274–88; 1927. *See* Just's Jber., Pt. 1, 945; 1927 and Bot. Zbl., N.S. **12**, 100; 1927.

1489. —— The comparative anatomy of the flax stem in connection with the yield of fibre in percentage. Bull. appld. Bot. Select. **19**, 1. 295–310; 1929. *See* Bot. Zbl., N.S. **17**, 133; 1930.

1490. MELVILLE, R. The botanical source of Indian Belladonna. J. Bot. **80**, 54; 1942.

1491. MERRILL, E. D. Some economic aspects of taxonomy. Torreya, **43**, 50–64; 1943.

1492. MÉNIAUD, J. *Nos bois coloniaux.* Paris, pp. 375; 1931.

1493. MESSERI, A. Studio anatomico-eculogico del legno secondario di alcune piante del Fezzan. Nuovo G. bot. ital. **45**, 267–356; 1938.

1494. METCALFE, C. R. The 'aerenchyma' of *Sesbania* and *Neptunia*. Kew Bull. No. 3, 151–4; 1931.

1494A. —— The breathing roots of *Sonneratia* and *Bruguiera*; a review of the recent work by Troll and Dragendorff. Kew Bull. No. 10, 465–7; 1931.

1495. —— A note on the structure of the phyllodes of *Oxalis Herrerae* R. Knuth and *O. bupleurifolia* St. Hil. Ann. Bot. Lond. **47**, 355–9; 1933.

1496. —— The structure and botanical identity of some scented woods from the East. Kew Bull. No. 1, 3–15; 1933.

1497. —— The structure of some sandalwoods and of their substitutes and of some other little-known scented woods. Kew Bull. No. 4, 165–94; 1935.

1498. —— Anatomy of *Fraxinus oxycarpa* and *F. pallisae*. Kew Bull. No. 6, 258–62; 1938.

1499. —— Extra-floral nectaries in *Osmanthus* leaves. Kew Bull. No. 6, 254–6; 1938.

1500. —— On the taxonomic value of the anatomical structure of the vegetative organs of the dicotyledons. I. An introduction, with special reference to the anatomy of the leaf and stem. Proc. Linn. Soc. Lond. **155**, 210–14; 1943.

1501. —— The role of the microscope in botanical identification. J. Quekett Micr. Cl., Ser. 4, **2**, 68–75; 1945.

1502. —— The systematic anatomy of the vegetative organs of the angiosperms. Biol. Rev. **21**, 159–72; 1946.

1503. METZLER, W. Beiträge zur vergleichenden Anatomie blattsukkulenten Pflanzen. Bot. Arch. **6**, 50–83; 1924.

1504. MEYER, F. J. *Bau und Ontogenie des Wasserleitungssystems der vegetativen Organe von Viola tricolor* var. *arvensis*. Thesis, Marburg, pp. 38; 1916. *See* Bot. Zbl. **141**, 211–12; 1919.

1505. —— Über Gefässdurchbrechungen und die Frage der Unterscheidung von Gefässen und Tracheiden. Jb. wiss. Bot. **71**, 161–83; 1929.

1506. MEYER, H. E. Avodiré, ein Nutzholz Westafrikas. Tropenpflanzen, **31**, 15–16; 1928.

1507. MEYER, J. E. The structure and strength of four North American woods as influenced by range, habitat and position in the tree. Tech. Publ. N.Y. St. Coll. For. **31**, pp. 39; 1930.

1508. MEYER, K. J. Sur la structure anatomique du *Sedum quadrifidum*. Bull. Soc. Nat. Moscou, **31**, 59–66; 1922. *See* Just's Jber. 328; 1924.

1509. MEYER, U. *Beiträge zur Pharmakognosie der Umbelliferen. Anatomie des Laubblattes.* Thesis, Basel, pp. 128; 1937.

1510. MEZ, C. *Theophrastaceae* in Engler's *Das Pflanzenreich*, iv. 236A; 1903.

1511. MICHELL, M. R. On the comparative anatomy of the genera *Ceraria* and *Portulacaria*. Ann. Bot. Lond. **26**, 1111–22; 1912.

1512. MICHLIN, J. *Recherches pharmaco-anatomiques sur Pimpinella saxifraga* L. *et Pimpinella magna* L. Thesis, Lausanne, pp. 136; 1926.

1513. MIEHE, H. Die sogenannten Eiweissdrüsen an der Blättern von *Ardisia crispa* A. DC. Ber. dtsch. bot. Ges. **29**, 156–7; 1911.

1514. —— Weitere Untersuchungen über die Bakteriensymbiose bei *Ardisia crispa*. II. Die Pflanze ohne Bakterien. Jb. wiss. Bot. **58**, 29–65; 1917.

1515. —— Anatomische Untersuchung der Pilzsymbiose bei *Casuarina equisetifolia* nebst einigen Bemerkungen über das Mykorhizenproblem. Flora, Jena, N.F. **11** and **12**, 431–49; 1918.

1516. —— Entwicklungsgeschichtliche Untersuchung der Algensymbiose bei *Gunnera macrophylla* Bl. Flora, Jena, N.S. **17**, 1–15; 1924.

1516A. MIERS, J. On *Goupia*. Ann. Nat. Hist. Ser. III, ix. 289–94; 1862.

1517. MILANEZ, F. R. A estrutura do lenho da embuia. Min. Agric. Ind. Com., Rio de Janeiro, pp. 12; 1930.

1518. —— Acção modificadora do oxalato de calcio sôbre as estruturas celulares. Revista Florestal, **2**, 5–12; 1932.

1519. —— Estrutura do lenho do *Mimusops Huberi*. Arch. Inst. Biol. veget. **1**, 49–62; 1934.

1520. —— Anatomia de *Paradrypetes ilicifolia*. Arch. Inst. Biol. veget. **2**, 133–56; 1935.

1521. —— Notas sôbre a galha lenhosa da goiabeira. Rodriguésia, **1**, 3–7; 1935.

1522. —— Anatomia do lenho do 'pau mulato'. Arch. Inst. Biol. veget. **3**, 111–29; 1936.

1523. —— Estrutura secundária das raizes de *Rhipsalis*. Rodriguésia, **5**, 165–75; 1936.

1524. —— Anatomia do lenho de *Ampelocera glabra* Kühlmann. Arch. Inst. Biol. veget. **3**, 211–15; 1937.

1525. —— Anatomia do lenho de '*Aspidosperma aquaticum*' Ducke. Arch. Inst. Biol. veget. **4**, 65–70; 1937.

—— On crystalliferous strands:

1526. I. Arch. Inst. Biol. veget. **4**, 79–85; 1937.

1527. II. Rodriguésia, **4**, 59–65; 1939.

1528. —— Trinta espécies do género 'Aspidosperma'. Physis, **15**, 429–90; 1939.

1529. —— Crystalliferous strands. Chronica bot. **7**, 68–9; 1942.

1530. —— Anatomia das principais madeiras Brasileiras das 'Rutaceae'. Rodriguésia, **7**, 3–22; 1943.

1531. —— Nota sôbre a classificação do parênquima do lenho. Rodriguésia, **8**, 1–3; 1944.

1532. MILDBRAED, J. *Stylidiaceae* in Engler's *Das Pflanzenreich*, iv. 278; 1908.

1533. —— Über die Gattung *Afrostyrax* Perk. et Gilg und *Hua* Pierre und die 'Knoblauch-Rinden' Westafrikas. Bot. Jb. **49**, 552–9; 1913.

1534. —— *Octonemaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* 16B; 1935.

MILLER, H. A., and WETMORE, R. H. Studies in the developmental anatomy of *Phlox drummondii* Hook.:

1535. II. The Seedling. Amer. J. Bot. **32**, 10. 628–34; 1945.

1536. III. The apices of the mature plant. Amer. J. Bot. **33**, 1–10; 1946.

1537. MILLER, R. B. The wood of *Machaerium Whitfordii*. Bull. Torrey bot. Cl. **47**, 73–9; 1920.

1538. MILLNER, M. E. Anatomy of *Silene vulgaris* and *Silene maritima* as related to ecological and genetical problems. 1. Root structure. New Phytol. **33**, 77–95; 1934.

1539. MIRANDE, M. Sur l'origine morphologique du liber interne des Nolanacées et la position systématique de cette famille. C. R. Acad. Sci. Paris, **175**, 375–6; 1922.

1540. MIRSKAJA, L. Ergänzungsvorgänge an längespaltenen Stämmen von *Mirabilis Jalapa*. Flora, Jena, **124,** 315–32; 1929/1930.

1541. MITCHELL, J. W., WHITING, G., and BENEDICT, H. M. Rubber content, stem anatomy and seed production as related to the rate of vegetative growth in Guayule. Bot. Gaz. **106,** 341–9; 1945.

1542. MITCHELL, W. B. G. *Identification of timbers available in the moist deciduous to savannah forests in Lagos Colony, Abeokuta, Ondo and Oyo Provinces.* Lagos, Nigeria, pp. 10; 1931.

1543. MITRA, G. C. The origin, development and morphology of the ochrea in *Polygonum orientale* L. J. Indian bot. Soc. **24,** 4. 191–9; 1945.

1544. MOHLER, P. *Beiträge zur Pharmakognosie der Urticales. Anatomie des Laubblattes.* Thesis, Basel, pp. 84; 1936.

1545. MOÏSEEVA, M. N. Anatomical structure of maple stems in relation to their phylogeny. Zhurnal. Inst. Bot. Vuan, **31,** 13–26; 1940. *See* Biol. Abstr. **16,** 3. No. 7820; 1942.

1546. MOKEEVA, E. Vergleichende Anatomie einiger verwandter Umbelliferae. Bull. Univ. Asie centr. **16,** 187–206; 1927. *See* Just's Jber., Pt. 1, 963; 1927 and Bot. Zbl., N.S. **13,** 7; 1928/9.

MOLISCH, H. Beiträge zur Mikrochemie der Pflanze:

1547. 1. Über einen leicht kristallisierenden Gerbstoff in *Dionaea muscipula.* Ber. dtsch. bot. Ges. **33,** 447–51; 1915.

1548. 2. Über orangefarbige Hydathoden bei *Ficus javanica.* Ber. dtsch. bot. Ges. **34,** 66–72; 1916.

1549. —— Rote Wurzelspitzen. Ber. dtsch. bot. Ges. **46,** 311–17; 1928.

1550. —— *Pflanzenchemie und Pflanzenverwandtschaft.* Jena, pp. 118; 1933.

1551. MONACHINO, J. A revision of *Couma* and *Parahancornia* (Apocynaceae). Lloydia, **6,** 229–47; 1943.

1552. MONOYER, A. Les variations vasculaires dues à la manière d'être des feuilles et l'établissement des types de structure. Arch. Inst. bot. Univ. Liége, **8,** 5, pp. 4; 1930.

1553. MONTCHEFF, R. Recherches sur l'anatomie des feuilles du genre *Cliffortia.* Univ. Genève Inst. bot., Sér. 8, **4,** pp. 96; 1909. *See* Bot. Zbl. **113,** 246; 1910.

1554. MORINI, F. Asservazioni anatomiche intorno ad alcune specie del genere *Loranthus* L. Mem. Acad. sci. Istituto Bologna, **7,** 419–25; 1910. *See* Just's Jber., Pt. 2, 1042; 1911.

1555. MORVILLEZ, M. F. Contributions à l'étude de quelques-uns des principaux types foliaires de la famille des Salicinées. Bull. Linn. Soc. N. Fr., pp. 31; 1912.

1556. —— La trace foliaire des Rosacées. C. R. Acad. Sci. Paris, **165,** 597–600; 1917.

1557. —— La trace foliaire des Chysobalanées. C. R. Acad. Sci. Paris, **166,** 859–61; 1918.

1558. —— La trace foliaire des Legumineuses-caesalpiniées. C. R. Acad. Sci. Paris, **167,** 205–8; 1918.

1559. —— L'appareil conducteur des feuilles des Saxifragacées. C. R. Acad. Sci. Paris, **167,** 555–7; 1918.

1560. —— L'appareil conducteur foliaire des Legumineuses, Papilionacées et Mimosées. C. R. Acad. Sci. Paris, **168,** 787–90; 1919.

1561. —— L'appareil conducteur foliaire des Hamamelidacées et des formes voisines. C. R. Acad. Sci. Paris, **169,** 542–5; 1919.

1562. —— L'appareil libéroligneux des Betulacées, Corylacées et Castanacées. C. R. Acad. Sci. Paris, **170,** 674–7; 1920.

1563. MOSER, H. Untersuchungen über die Blattstruktur von *Atriplex*-Arten und ihre Beziehungen zur Systematik. Beih. bot. Zbl. **52,** 2. 378–88; 1934.

1564. MOSS, E. H. The ecology of *Epilobium angustifolium* with particular reference to rings of periderm in the wood. Amer. J. Bot. **23,** 14–20; 1936.

1565. Moss, E. H. Interxylary cork in *Artemisia* with a reference to its taxonomic significance. Amer. J. Bot. **27**, 762–8; 1940.

1566. Motte, J. Sur les nodules subéreux des feuilles d'*Eucalyptus globosus*. Bull. Soc. bot. Fr. **73**, 1028–32; 1926.

1567. Moyer, L. S. Species relationships in *Euphorbia* as shown by electrophoresis of latex. Amer. J. Bot. **21**, 293–313; 1934.

1568. Mühldorf, A. Ein neuer xeromorpher Spaltöffnungsapparat bei Dicotylen. Öst. bot. Z. **71**, 50–4; 1922.

1569. Mullan, D. P. Observations on the water-storing devices in the leaves of some Indian halophytes. J. Indian bot. Soc. **10**, 126–34; 1931.

1570. —— On the occurrence of glandular hairs (salt glands) on the leaves of some Indian halophytes. J. Indian bot. Soc. **10**, 184–9; 1931.

1571. —— Observations on the biology and physiological anatomy of some Indian halophytes. J. Indian bot. Soc. **11**, 103–18 and 285–302; 1932 and **12**, 165–82; 1933 and **12**, 235–53; 1933.

1572. Muller, R. Zur Anatomie der *Ailanthus*-Rinden. Pharm. Praxis, **7**, 261–3; 1908. *See* Just's Jber., Pt. 1, 473; 1908.

1573. Mulsow, F. W. Differentiation of the oaks by histological methods. Kans. Univ. Sci. Bull. **9**, 271–7; 1915.

1574. Munch, J. C., and Crosbye, H. H. Bioassey of aconite and its preparations. 2. The pharmacology and pharmacognosy of various species of *Aconitum*. J. Amer. pharm. Ass. **18**, 986–92; 1929.

1575. Murray, J. Anatomical features in the roots of the genus *Primula*. Trans. bot. Soc. Edinb. **31**, 3. 323–6; 1934.

1576. Musson, C. T., and Carne, W. M. The adventitious roots of *Melaleuca linarifolia* Sm. Proc. Linn. Soc. N.S.W. **35**, 662–5; 1910.

1577. Myers, L. Tyloses in *Menispermum*. Bot. Gaz. **78**, 453–6; 1924.

1578. Nagel, K. Studien über die Familie der Juglandaceen. Bot. Jb. **50**, 459-530; 1914. *See* Just's Jber., Pt. 1, 877; 1914.

1579. Nassanov, V. A. Anatomical characteristics of the geographical races of hemp. Soviet Plant Industry Record, **4**, 107–20; 1940. *See* Plant Breeding Abstr. **12**, 829; 1942.

1580. Nast, C. G. The comparative morphology of the Winteraceae. VI. Vascular anatomy of the flowering shoot. J. Arnold Arbor. **25**, 454–66; 1944.

1581. Nast, C. G., and Bailey, I. W. Morphology and relationships of *Trochodendron* and *Tetracentron*. II. Inflorescence, flower and fruit. J. Arnold Arbor. **26**, 267–76; 1945.

1582. Navez, A. E. On the distribution of tabular roots in *Ceiba* (Bombacaceae). Proc. nat. Acad. Sci. Wash. **16**, 339–44; 1930.

1583. Neeff, F. Über die Umlagerung der Kambiumzellen beim Dickenwachstum der Dicotylen. Z. Bot. **12**, 225–52; 1920.

1584. Negodi, G. Contributo alla conoscenza di un gruppo di specie del genere *Plantago* appartenenti alla sezione *Biconvexae* Boiss. Nuovo G. bot. Ital., N.S. **36**, 624–41; 1929. *See* Bot. Zbl., N.S. **18**, 451; 1931.

1585. Neithammer, A. Beiträge zur Keimungsbiologie und physiologischen Anatomie der Früchte von *Tragopogon pratensis* L. Beih. bot. Zbl. **47**, 1. 282–90; 1930.

1586. Nestler, A. Zur Kenntnis der Wirkung der Brennhaare unserer *Urtica*-Arten. Ber. dtsch. bot. Ges. **43**, 497–504; 1925.

1587. Nestler, H. Beiträge zur systematischen Kenntnis der Gattung *Linum*. Beih. bot. Zbl. **50**, 2. 497–551; 1933.

1588. Netolitzky, F. *Die Pflanzenhaare*. Berlin, pp. 253; 1932.

1589. Nickiporovich, A. A., Ostapenko, L. A., and Vassiljeva, N. G. Anatomical peculiarities of diploid and polyploid forms of the rubber yielding plant *Taraxacum kok-saghyz* Rodin. Bull. Acad. Sci. U.R.S.S. ser. Biol., No. 2, 309–31; 1941. Summary in Plant Breeding Abstr. **12**, 3, No. 846; 1942.

1590. NICOLAS, G. Remarques sur la structure des organes souterrains du *Thrincia tuberosa* DC. Bull. Soc. Hist. nat. Afr. N. **4,** 9–16; 1913. *See* Bot. Zbl. **132,** 517–18; 1916.

1591. —— Observations sur la structure des racines du *Ranunculus bullatus* L. Bull. Soc. bot. Hist. nat. Afr. N. **5,** 62–5; 1914. *See* Bot. Zbl. **132,** 498; 1916.

1592. —— Remarques sur l'épiderme des feuilles de quelques *Galium.* Bull. Soc. Hist. nat. Toulouse, **58,** 45–6; 1929. *See* Bull. Soc. bot. Fr. **77,** 529; 1930.

1593. NICOLOFF, T. Contribution à l'histologie et à la physiologie des rayons médullaires chez les Dicotylédones arborescentes. Rev. gén. Bot. **23,** 369–403; 1911.

1594. NIEDENZU, F. Die Anatomie der Laubblätter der palaeotropischen Malpighiaceae. Vorl. Verz. Braunsberg S.S. 3–10; 1922. *See* Just's Jber. 597; 1922 and Bot. Zbl., N.F. **2,** 131; 1922/3.

1595. —— *Elatinaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

1596. —— *Frankeniaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

1597. —— *Tamaricaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

1598. —— *Malpighiaceae* in Engler's *Das Pflanzenreich*, iv. 141; 1928.

1599. NIEDENZU, F., and ENGLER, A. *Myrothamnaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 18A; 1930.

1600. NIEDENZU, FR., and HARMS, H. *Bruniaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 18A; 1930.

1601. NIESEMANN, H. W. *Das anormale Dickenwachstum von Mendoncia velloziana Mart. und Afromendoncia Lindaviana Gilg.* Thesis, Berlin, pp. 53; 1927. *See* Bot. Zbl. **12,** 260; 1927.

1602. NIGHTINGALE, G. T., and FARNHAM, R. B. Effects of nutrient concentration on anatomy, metabolism and bud abscission of sweet pea. Bot. Gaz. **97,** 477–517; 1935.

1603. NOELLI, A. Sull' origine delle lenticelle nel *Sambucus nigra* L. Bull. Soc. bot. Ital. 65–71; 1926. *See* Bull. Soc. bot. Fr. **74,** 1002; 1927.

1604. NOMMEUSEN, R. *Beiträge zur Kenntnis der Anatomie der Cacteen, insbesondere ihres Hautgewebes.* Thesis, Kiel, pp. 53; 1910. *See* Just's Jber., Pt. 2, 1591; 1910.

1605. NORDHAUSEN, M. Über kontraktile Luftwurzeln. Flora, Jena, **105,** 101–26; 1913. *See* Just's Jber., Pt. 2, 1119; 1913.

1606. NORMAND, D. Note sur *Gmelina arborea* Roxb., essence de repeuplement pour la fôret tropicale asiatique. Rev. Bot. appl. **115,** 168–74; 1931.

1607. —— Note sur les bois d'*Enantia* (Annonacées). Bull. Jard. bot. Brux. **9,** 317–22; 1933.

1608. —— Le bois de *Guarea Thompsonii,* succédanée du Bossé. Rev. Bot. appl. **137,** 23–30; 1933.

1609. —— Les bois des Myristicacées du Gabon. Rev. Bot. appl. **143,** 471–79; 1933.

1610. —— Aperçu sur la systématique des bois. Rev. int. du Bois, **1,** 11. 15–25; 1934.

1611. —— Note sur le bois de Difou. Rev. Bot. appl. **14,** 253–56; 1934.

1612. —— Note sur quelques bois du Gabon. Rev. Bot. appl. **154,** 414–21; 1934.

1613. —— Sur le *Maesopsis* de l'Ouest Africain et le bois de Nkanguele. Rev. Bot. appl. **164,** 252–63; 1935.

1614. —— Le bois de Landa, *Erythroxylum* du Cameroun. Rev. Bot. appl. **196,** 883–9; 1937.

1615. —— Description du bois d'*Ibadja Walkeri* A. Chev. Rev. Bot. appl. **18,** 789–91; 1938.

1616. —— Identification et emplois des bois d'*Afzelia.* Rev. Bot. appl. **19,** 488–94; 1939.

1617. Normand, D. Anatomie du bois du genre nouveau '*Okoubaka*'. Bull. Soc. bot. Fr. **91**, 20–5; 1944.

1618. —— Introduction à l'étude descriptive des bois tropicaux. Trav. Section Technique d'Agriculture Tropicale, **1**, 111–35; 1945.

1619. —— L'identification des bois de la Côte d'Ivoire. Rev. l'Agron. trop. **1**, 361–74; 1946.

1620. —— Anatomie des bois d'*Endodesmia* et de *Lebrunia*. Bull. Soc. bot. Fr. **93**, 245–8; 1946.

1621. —— Note sur les bois de Zingana et autre Caesalpiniées africaines à très petites folioles. Rev. Bot. appl. **27**, 139–50; 1947.

1622. Normand, D., and Besson, A. Caractéristiques des bois tropicaux. Rev. du Bois et ses Applications, **1**, 3–10; 1946.

1623. Nyrac, J. P. *Recherches anatomiques sur les Antirrhinées*. Thesis, Paris, pp. 89; 1916.

1624. Obaton, F. Structure comparée des feuilles de même age et de dimensions différentes. C. R. Acad. Sci. Paris, **173**, 1113–16; 1921. *See* Bot. Zbl., NF. **1**, 294; 1922.

1625. Obermeyer, A. Vergleichende anatomisch-pharmakognostische Untersuchung der heute gebräuchlichen Krautdrogen des Genus *Artemisia*. Ber. schweiz. bot. Ges. **47**, 29–123; 1937.

1626. Oberstein, O. Über den Bau der Blattspitzen der Mesembrianthema-Barbata. Beih. bot. Zbl. **29**, 1. 298–302; 1912.

1627. —— Über das Auftreten von Gerbstoffidioblasten bei den Mesembrianthemen. Beih. bot. Zbl. **31**, 1. 388–93; 1913.

1628. Odell, M. E. The determination of fossil angiosperms by the characteristics of the vegetative organs. Ann. Bot. Lond. **46**, 941–63; 1932.

1629. O'Donell, C. A. Anatomía comparada del leño de tres Simarubaceas argentinas. Lilloa, **1**, 263–82; 1937.

1630. —— Posición sistemática de '*Diclidanthera*' Mart. Lilloa, **6**, 207–12; 1941.

1631. O'Donell, C. A., and Lourteig, A. Malpighiaceae Argentinae. Lilloa, **9**, 221–36; 1943.

1632. Oehm, G. Beitrag zur Kenntnis der Blattanatomie und Behaarung von *Plantago media* L. *Pl. major* L. und *Pl. lanceolata* L., mit besonderer Berücksichtigung der Unterscheidungsmöglichkeit der Blätter auch in Bruchstücken. Beih. bot. Zbl., N.S. **50**, 1. 20–43; 1932/33.

1633. —— Vergleichende Untersuchungen über Blattoberflächenmerkmale einiger stark behaarter *Digitalis*-arten, mit besonderer Berücksichtigung der Kutikulargestaltung an Oberhautzellen und Haaren. Beih. bot. Zbl. **53**, 2. 485–517; 1935.

1634. Ohara, K. Über die Verwendung des Aschenbildes für die Bestimmung technisch verwendeten Hölzer. Denkschr. Akad. Wiss. Wien, **100**, 301–20; 1926.

1635. Ohara, K., and Kondo, Y. Aschenbilder der Drogenblätter in Pharmacopoea Japonica IV. J. Pharm. Soc. Japan, **49**, 11; 1929. *See* Jap. J. Bot. **5**, 17; 1931/2.

1636. Ohtani, F. Über den Bau des Blattrandes bei Myrtaceen, Hamamelidaceen, Lauraceen und Monimiaceen. Festschr. A. Tschirch, 299; 1926. *See* Just's Jber., Pt. 2, 456; 1926.

1637. Oliver, W. R. B. The vegetation and flora of Lord Howe Island. Trans. N. Zealand Inst. **49**, 94–161; 1916.

1638. Olsen, C. The structure and biology of Arctic flowering plants. II. Cornaceae. Meddel. om Gronland, **37**, 127–50; 1914. *See* Just's Jber., Pt. 1, 246; 1920.

1639. Orr, M. Y. Intumescences on the leaves of *Marlea begoniifolia*. Notes R. bot. Gdn. Edinb. **12**, 258; 1921.

1640. Orsos, O. Gewebentwicklung bei der Kohlrabiknolle. Flora, Jena, N.S. **35**, 6–20; 1941.

1641. Ortega, J. G. La Guázima. Méx. for. **12,** 166–88; 1934.

1642. Ossowski, A. O mieszanym pierścieniu mechanicznym w nerwie głównym liści Lauraceae. Zakładu Farmakognozji i Botaniki lekarskiej Uniwerstytetu Warszawskiego, pp. 14; 1929. Polish with English summary.

1643. —— The formation of intumescences containing fatty substances in the stem of *Khaya ivorensis*. Kew Bull. No. 4, 137–41; 1938.

1644. Osterwalder, R. *Beiträge zur Kenntnis pharmazeut wichtiger Gentiana-Wurzeln.* Thesis, Basel, pp. 102; 1919. *See* Schweiz ApothZtg. **58,** 201; 1920.

1645. Ozenda, P. Sur la vascularization des carpelles et du pistil chez les Magnolia. C. R. Acad. Sci. Paris, **217,** 31–3; 1943.

1646. —— Sur l'anatomie libéroligneuse des Schizandracées. C. R. Acad. Sci. Paris, **223,** 207–9; 1946.

1647. —— Structure du nœud foliaire des Magnoliacées et des Annonacées. C. R. Acad. Sci. Paris, **224,** 1521–3; 1947.

1648. Oztig, O. F. Beiträge zur Kenntnis des Baues der Blattepidermis bei den Mesembrianthemum im besonderen den extrem xeromorphen Arten. Flora, Jena, N.S. **34,** 105–44; 1940.

1649. Panshin, A. J. An anatomical study of the woods of the Philippine mangrove swamps. Philipp. J. Sci. **48,** 143–207; 1932.

1650. —— Comparative anatomy of the woods of the Meliaceae, sub-family Swietenioideae. Amer. J. Bot. **20,** 639–68; 1933.

1651. —— Wood anatomy of certain South American rotenone-yielding plants. Amer. J. Bot. **24,** 587–91; 1937.

1652. Parham, B. E. New Zealand beech timbers: their structure and identification. N.Z. J. Sci. & Tech. **14,** 233–40 and 372–82; 1933.

1653. Parija, P., and Misra, P. The 'root-thorn' of *Bridelia pubescens* Kurz. J. Indian bot. Soc. **12,** 227–33; 1933.

1654. Parkin, J. *Eucommia ulmoides*, the tu-chung of the Chinese. Kew Bull. No. 5, 177–85; 1921.

1655. Parmentier, P. Recherches anatomiques et taxonomiques sur les Juglandacées. Rev. gén. Bot. **23,** 341–63; 1911.

1656. Parrot, A. G. Étude morphologique et anatomique d'une curieuse plantule de carotte. Bull. Soc. bot. Fr. **89,** 100–2; 1942.

1657. Parsa, A. Anatomie de *Lathyrus szowitsii* Boiss. Bull. Soc. bot. Fr. **83,** 4–5; 1936.

1658. Pasqualet, M. Contribution à l'étude des Tiliacées textiles de l'Afrique équatoriale et Cameroun. Bull. Soc. bot. Fr. **73,** 230–8; 1926.

1659. Pax, F. *Staphyleaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 5; 1896.

1660. —— *Hippocastanaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 5; 1896.

1661. —— *Moringaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 1894, and Auf. 2, 17B; 1936.

1662. —— *Euphorbiaceae-Jatropheae* in Engler's *Das Pflanzenreich,* iv. 147 I; 1910.

1663. —— *Euphorbiaceae-Adrianeae* in Engler's *Das Pflanzenreich,* iv. 147 II; 1910.

1664. —— *Euphorbiaceae-Cluytieae* in Engler's *Das Pflanzenreich,* iv. 147 III; 1911.

1665. —— *Euphorbiaceae-Gelonieae* in Engler's *Das Pflanzenreich,* iv. 147 IV; 1912.

1666. —— *Euphorbiaceae-Hippomaneae* in Engler's *Das Pflanzenreich,* iv. 147 V; 1912.

1667. —— *Euphorbiaceae-Acalypheae-Chrozophorinae* in Engler's *Das Pflanzenreich,* iv. 147 VI; 1912.

1668. —— *Euphorbiaceae-Acalypheae-Mercurialinae* in Engler's *Das Pflanzenreich,* iv. 147 VII; 1914.

1669. Pax, F., and Hoffmann, K. *Euphorbiaceae-Acalypheae-Plukenetiinae. Euphorbiaceae-Acalypheae-Epiprininae. Euphorbiaceae-Acalypheae-Ricininae* in Engler's *Das Pflanzenreich,* iv. 147 IX–XI; 1919.

1670. Pax, F., and Hoffmann, K. *Euphorbiaceae-Phyllanthoideae-Phyllantheae* in Engler's *Das Pflanzenreich*, iv. 147 xv; 1922.

1671. —— *Euphorbiaceae-Crotonoideae-Acalypheae-Acalyphinae* in Engler's *Das Pflanzenreich*, iv. 147 xvi; 1924.

1672. —— *Euphorbiaceae-Additamentum VII* in Engler's *Das Pflanzenreich*, iv. 147 xvii; 1924.

1673. —— *Euphorbiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19c; 1931.

1674. —— *Callitrichaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19c; 1931.

1675. —— *Aizoaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16c; 1934.

1676. —— *Portulacaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16c; 1934.

1677. —— *Caryophyllaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16c; 1934.

1678. —— *Capparidaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 17b; 1936.

1679. Pearson, R. S., and Brown, H. P. *Commercial timbers of India.* Govt. of India Central Publication Branch, Calcutta. Vols. i and ii, pp. 1150; 1932.

1680. Pegg, E. J. An ecological study of some New Zealand sand-dune plants. Trans. N. Zealand Inst. **46**, 150–77; 1913.

1681. Pekelharing, N. R. *Systematisch-anatomische Untersuchungen des Baues der Blattspreite in der Familie der Theaceae.* Thesis, Groningen, pp. 113; 1908. *See* Just's Jber., Pt. 1, 998; 1909.

1682. Pellegrin, F. Recherches anatomiques sur la classification des genêts et des Cytises. Thesis, Paris, pp. 90; 1908 and Ann. Sci. nat. b., Ser. 9, **7**, 129–319; 1908.

1683. Pellisier, F. Sur la différenciation vasculaire dans les feuilles de *Cucurbita pepo.* Bull. Soc. bot. Fr. **86**, 3 & 4. 187–90; 1939.

1684. —— La constance du nombre des faisceaux dans le genre *Cucurbita.* Bull. Soc. bot. Fr. **87**, 23–7; 1940.

1685. Penfound, W. T. The anatomy of the castor bean as conditioned by light intensity and soil moisture. Amer. J. Bot. **19**, 538–46; 1932.

1686. —— Comparative structure of the wood in the 'knees', swollen bases, and normal trunks of the Tupelo gum (*Nyssa aquatica* L.). Amer. J. Bot. **21**, 623–31; 1934.

1687. Pereira, J. A. Contribuïção para a Identificação Micrográphica das nossas Maderas. Bull. Escola Polytéchnica de São Paulo, Brazil, No. 9, pp. 165; 1933.

1688. Pergola, de D. Alcune notizie su l'*Haloxylon schmittianum* e sul suo impiego. Archivio di farmacologia e scienze affini Roma, **2**, 209–13; 1913. *See* Just's Jber., Pt. 2, 1089; 1913.

1689. Perkins, J. *Styracaceae* in Engler's *Das Pflanzenreich*, iv. 241; 1907.

1690. Perrédès, P. E. F. Comparative anatomy of the barks of the Salicaceae (Part I). Publication 39, Wellcome Chemical Research Laboratories. Pharm. J., Ser. 4, **17**, 171–82; 1903.

1691. Perrot, E. *Anatomie comparée des Gentianacées.* Thesis, Paris, pp. 294; 1897.

—— *Essai d'identification des bois tropicaux:*

1692. *Les bois du Gabon*, vol. i, Paris, 1921.

1693. *Les bois de la Côte d'Ivoire*, vol. i, Paris, 1922.

1694. *Les bois de Madagascar*, vols. i and ii, Paris, 1922.

1695. —— Les santals d'Australie et leurs essences. Bull. Sci. Pharm. **34**, 609–41; 1927 and Trav. Lab. Mat. méd. Paris, **18**, pp. 32; 1927.

1696. Perrot, E., and Hubert, G. Sur quelques particularités histologiques que l'on observe dans le pétiole et la feuille des Verbenacées. Trav. Lab. Mat. méd. Paris, **14**, 71–5; 1922. *See* Just's Jber., Pt. 1, 676; 1923.

1697. Perrot, E., and Morel, F. Quelques remarques sur l'anatomie des Ombellifères. Bull. Soc. bot. Fr. **60**, 99–106 and 141–50; 1913.

1698. Perrot, E., and Hamet, Raymond. Yagé, Ayahuasca Caapi et leur alcaloide: telepathine ou yagéine. Trav. Lab. Mat. méd. Paris, **18**, pp. 35; 1927.

1699. Perry, B. A. Chromosome numbers and phylogenetic relationships in the Euphorbiaceae. Amer. J. Bot. **30**, 527–43; 1943.

1700. Petaj, V. Die extrafloralen Nektarien auf den Blättern von *Ailanthus glandulosa*. Rad. Jugosl. akad. znanosti Kuj. **215**, 59–81; 1916. *See* Bot. Zbl. **137**, 385; 1918.

1701. Petch, T. The girth increment of *Hevea brasiliensis*. Ann. Roy. bot. Gard. Peradeniya, **6**, 77–86; 1916.

1702. Peters, P. Zur Entstehung des Phyllodiums von *Acacia* aus dem Blattstiel. Ber. dtsch. bot. Ges. **43**, 171–8; 1925.

1703. Peters, T. Über die Bedeutung der inversen Leitbündel für die Phyllodien-Theorie. Planta, **3**, 90–9; 1927.

1704. Petersen, H. E. Ericineae. The biological anatomy of the leaves and stems. Meddel. om Grønland, **36**, 73–138; 1908.

1705. —— The structure and biology of Arctic flowering plants. I. Diapensiaceae. Meddel. om Grønland, **36**, 139–64; 1909.

1706. —— Some preliminary remarks on the origin of isolated vascular bundles in herbaceous dicotyledonous plants. Bot. Tidsskr., **37**, 136–46; 1920.

1707. Pfeiffer, H. Über Exkrete und Exkretionsbehälter einiger Dikotyledonen. Mikrokosmos, **13**, 146–51, 185–90, 208–11; 1919/20. *See* Just's Jber., Pt. 1, 266; 1920.

1708. —— Neue Untersuchungen über abnormes Dickenwachstum einheimischer Pflanzen. 3. Über Achsenanatomie und Dickenwachstum der nordwestdeutschen *Chenopodium*-Arten. 4. Vom Dickenwachstum des Mangold (*Beta vulgaris*). Mikroscop. f. Naturfr. **1**, pp. 7; 1923.

1709. —— Anatomische Untersuchungen an der griechischen Baumschlinge *Periploca graeca* L. (*P. maculata* Moench). Schriften d. Vereinig. v. Freunden d. Mikrosk. **1**, 1–4; 1923. *See* Bot. Zbl., N.S. **4**, 66; 1924.

1710. —— Über Spaltenbildung von Vorbeigleiten der Bastkörper im unterbrochenen Holzkörper der Bignoniaceen. Ber. dtsch. bot. Ges. **42**, 32–5; 1924.

1711. —— Anatomische Betrachtung brasilianischer Hölzer. Beih. bot. Zbl. **41**, 165–77; 1925.

1712. —— *Das abnorme Dickenwachstum.* Linsbauer, Handbuch der Pflanzenanatomie, vol. 9, Berlin, 1926.

1713. Pfeiffer, J. Ph. De Houtsoorten van Suriname I. Meded. kolon. Inst. Amst., No. 22 (Handelsmus. No. 6), Part I, pp. 505; 1926.

1714. Pfeiffer, J. Ph., and Varossieau, W. W. Classification of the structural elements of the secondary wood of dicotyledons, using decimal indices for classification and identification of wood species. Blumea, **5**, 437–89; 1945.

1715. Phillips, E. W. J. The depletion of starch from timber in relation to attack by *Lyctus* beetles. 1. Starch, with special reference to its occurrence in timber. Forestry, **12**, 15–29; 1938.

1716. Piccioli, E. Researches on foreign woods. Mahogany-Cedrela. Staz. sper. agr. ital. **55**, 51–79; 1923.

1717. Pierce, J. H. The nomenclature of Balsa wood (*Ochroma*). Trop. Woods, **69**, 1–2; 1942.

1718. —— An evaluation of the type material of *Ochroma*, the source of Balsa wood. Trop. Woods, **70**, 20–32; 1942.

1719. Piggott, E. Observations on *Corynocarpus laevigata* Forst., the karaka. Trans. N. Zealand Inst. **58**, 57–71; 1927.

1720. Pilger, R. Eine neue Gattung der Aizoaceae. Bot. Jb. **40,** 396–7; 1908.

1721. —— *Caryocaraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

1722. —— *Bixaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

1723. —— *Cochlospermaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

1724. —— *Santalaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16B; 1935.

1725. —— *Plantaginaceae* in Engler's *Das Pflanzenreich*, iv. 269; 1937.

1726. Pirschle, K. Zur Lage der Zellkerne in den Sekretkanälen der Umbelliferen. Öst. bot. Z. **75,** 96–105; 1926.

1727. Planchon, L. Recherches sur les *Erythrophloeum* et en particulier sur le *E. Couminga* H. Bon. Ann. Inst. col. Marseille, Sér. 2, **5,** 161–304; 1907. *See* Just's Jber., Pt. 1, 450; 1908.

1728. —— Sur le *Sarcocaulon Patersonii* Eckl. et Zeyh. Ann. Mus. colon. Marseille, **9,** 291–302; 1911. *See* Just's Jber., Pt. 2, 1043; 1911.

1729. —— Sur l'*Erythrophloeum densiflorum* (Elm.) Merr. Ann. Mus. colon. Marseille, 303–29; 1911. *See* Just's Jber., Pt. 2, 1044; 1911.

1730. —— Sur l'*Osyris alba* L. Bull. Soc. bot. Fr. **59,** 108–12; 1912.

1731. Plaut, M. Epiblem, Hypodermis und Endodermis der Zuckerrübe. Mitt. Kaiser-Wilhelm-Instituts Landwirtsch. in Bromberg, **3,** 2. 63–9; 1910. *See* Just's Jber., Pt. 2, 1064; 1910.

1732. Plowman, A. B. Is the box elder a maple? A study of the comparative anatomy of *Negundo.* Bot. Gaz. **60,** 169–92; 1915.

1733. Ponzo, A. Considerazioni sulli Cistaceae. Nuovo G. bot. Ital., n.s. **28,** 157–73; 1921.

1734. Popham, R. A. *The developmental anatomy of Jatropha cordata* (*Orteg.*) *Muell.* Thesis, Ohio Stat. Univ. **34,** 485–97; 1940. *See* Biol. Abstr. **15,** No. 24178; 1941.

1735. Pottier, J. *Recherches sur l'anatomie comparée dans la famille des Elatinacées et sur le développement de la tige et de la racine dans le genre Elatine.* Thesis, Besançon, pp. 157; 1927.

1736. Poulsen, V. A. *Pentaphragma ellipticum.* Vidensk. Medd. naturh. Foren. Kbh. 319–30; 1903.

1737. —— Bidrag til Rodens Anatomi. Biolog. Arb. tilegnede Eug. Warming, Kopenhagen, 183–91; 1911. *See* Just's Jber., Pt. 2, 1049; 1911.

1738. —— Plantenanatomiske Bidrag. Anatomiske Bemærkninger om Bladbygningen hos nogle Apocynaceer. Vidensk Medd. naturh. Foren. Kbh. **68,** 299–307; 1917.

1739. Pratt, D. J. An anatomical study of *Cycloloma atriplicifolium.* Kans. Univ. Sci. Bull. **10,** 87–120; 1917. *See* Just's Jber., Pt. 1, 247; 1920.

1740. Preston, R. D. Some physical properties of the multiperforate cross-walls of xylem vessels of *Helianthus annuus.* Proc. Leeds phil. lit. Soc. **3,** 102–5; 1935.

1741. Price, S. R. Note on oil-bodies in the mesophyll of the cherry laurel leaf. New Phytol. **11,** 371–2; 1912.

1742. Prichard, R. P., and Bailey, I. W. The significance of certain variations in the anatomical structure of wood. For. Quart. **14,** 662–71; 1916.

1743. Priestley, J. H. The fundamental fat metabolism of the plant. New Phytol. **23,** 1–19; 1924.

1744. —— The meristematic tissues of the plant. Biol. Rev. **3,** 1–20; 1928.

1745. — Studies in the physiology of cambial activity. I. Contrasted types of cambial activity. II. The concept of sliding growth. III. The seasonal activity of the cambium. New Phytol. **29,** 56–73, 96–140, and 316–54; 1930.

1746. Priestley, J. H. The growing tree. Nature, Lond. **130**, 494–7; 1932.

Priestley, J. H., *et al.* Physiological studies in plant anatomy:

(and Armstead, D.)

1747. II. The physiological relation of the surrounding tissue to the xylem and its contents. New Phytol. **21**, 62–80; 1922.

(and North, E. E.)

1748. III. The structure of the endodermis in relation to its function. New Phytol. **21**, 113–39; 1922.

(and Tupper-Carey, R. M.)

1749. IV. The water relations of the plant growing point. New Phytol. **21**, 210–29; 1922.

(and Ewing, J.)

1750. VI. Etiolation. New Phytol. **22**, 30–44; 1923.

1751. Priestley, J. H., and Hinchliff, M. The physiological anatomy of the vascular plants characteristic of peat. Naturalist, Lond. 263–8; 1922.

1752. Priestley, J. H., and Scott, L. A note upon summer wood production in the tree. Proc. Leeds phil. lit. Soc. **3**, 235–48; 1936.

1753. —— The vascular anatomy of *Helianthus annuus* L. Proc. Leeds phil. lit. Soc. **3**, 159–73; 1936.

1754. Priestley, J. H., Scott, L., and Malins, M. E. Vessel development in angiosperms. Proc. Leeds phil. lit. Soc. **3**, 42–54; 1935.

1755. Priestley, J. H., and Swingle, C. F. *Vegetative propagation from the standpoint of plant anatomy.* Tech. Bull. U.S. Dept. Agric., No. 151, pp. 98; 1929.

1756. Priestley, J. H., and Tong, D. The effect of gravity upon the cambial activity in trees. Proc. Leeds phil. lit. Soc. **1**, 199–208; 1927.

1757. Priestley, J. H., and Woffenden, L. M. V. Causal factors in cork formation. New Phytol. **21**, 252–68; 1922.

1758. Pritzel, E. *Pittosporaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 18a; 1930.

1759. Privault, D. Remarques anatomiques et biologiques sur quelques plantes de la Martinique. Bull. Soc. bot. Fr. **85**, 157–9; 1938.

1760. Prodinger, M. Das Periderm der Rosaceen in systematischer Beziehung. Denkschr. Akad. Wiss. Wien, **84**, 328–83; 1908. *See* Just's Jber., Pt. 1, 477; 1908.

1761. Puech, M. G. Étude anatomique de quelques espèces d'Asclépiadées aphylles de l'ouest de Madagascar. Rev. gén. Bot. **24**, 298–312 and 329–43; 1912.

1762. Puri, G. S. Some fossil leaves of the Ulmaceae from the Karewa deposits of Kashmir. J. Indian bot. Soc. **24**, 4. 183–90; 1945.

1763. —— The occurrence of *Parrotia jacquemontiana* Don. in the Pleistocene of Kashmir. Current Sci. **15**, 13–14; 1946.

1764. Quazilbash, N. A. Some observations on Indian Artemisia. Quart. J. Pharm. **15**, 323–31; 1942. *See* Biol. Abstr. **17**, No. 14560; 1943.

1765. Quentin, J. *Contribution à l'étude anatomique des espèces du genre Baccharis.* Thesis, Paris, pp. 76; 1911.

1766. Queva, C. Le *Monotropa Hypopitys* L. Anatomie et biologie. *See* Bull. Soc. bot. Fr. **57**, 639; 1910.

1767. Quinlan, Ch. E. Contributions towards a knowledge of the anatomy of the lower dicotyledons. III. The anatomy of the stem of the Calycanthaceae. Trans. roy. Soc. Edinb. **52**, 517–30; 1920. *See* Just's Jber., Pt. 1, 248; 1920.

1768. Quisumbing, E. The occurrence of laticiferous vessels in the mature bark of *Hevea brasiliensis.* Univ. Calif. Publ. Bot. **13**, 319–32; 1927. *See* Just's Jber., Pt. 1, 947; 1927.

1769. Rabbas, P. *Beiträge zur Kenntnis des Wachstums der Ranunculaceenwurzel.* Thesis, Berlin, pp. 45; 1913.

1770. Radlkofer, L. *Sapindaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 5; 1896 and Engler's *Das Pflanzenreich*, iv. 165; 1934.

1771. Rafalski, J., and Stryla, S. Badania nad drewnem piniora brazylijskiego (*Araucaria brasiliana* Lamb.) i peroby różowej (*Aspidosperma polyneuron* Muell. Arg.). Roczników Nauk Rolniczych i Leśnych (Poland), **46,** 229–64; 1939.

1772. Rao, L. A. Parasitism in the Santalaceae. Ann. Bot. Lond., n.s. **6,** 131–50; 1942.

1773. Rao, L. N. A short note on the extra-floral nectaries in *Spathodea stipulata.* J. Indian bot. Soc. **5,** 113–16; 1926.

1774. Rea, M. W. Stomata and hydathodes in *Campanula rotundifolia* L. and their relation to environment. New Phytol. **20,** 56–82; 1921.

1775. Record, S. J. Pith flecks or medullary spots in wood. For. Quart. **9,** 244–52; 1911.

1776. —— Tier-like structure of some woods. Hardwood Rec. (Chicago), **34,** 38–9; 1912.

1777. —— Tier-like arrangement of the elements of certain woods. Science, n.s. **36,** 889. 75–7; 1912.

1778. —— Differentiating between maples. Hardwood Rec. (Chicago), **36,** 26–7; 1913.

1779. —— Ray tracheid in *Quercus alba*. Bot. Gaz. **64,** 437; 1917.

1780. —— Intercellular canals in dicotyledonous woods. J. For. **16,** 428–41; 1918.

1781. —— Storied or tier-like structure of certain dicotyledonous woods. Bull. Torrey bot. Cl. **46,** 253–73; 1919.

1782. —— Mahogany and some of its substitutes. J. For. **17,** 1–8; 1919.

1783. —— *Identification of the economic woods of the United States.* New York, pp. 157; 1919.

1784. —— The wood of the Venezuelan mahogany (*Swietenia Candollei* Pittier). Bol. Com. & Ind. (Caracas), **18,** 557–81; 1921.

1785. —— Boxwoods of commerce. Bull. Torrey bot. Cl. **48,** 297–306; 1921.

1786. —— *Lignum-vitae: A study of the woods of the Zygophyllaceae with reference to the true Lignum-vitae of commerce.* Bull. Yale Sch. For., No. 6, pp. 48; 1921.

1787. —— Further notes on intercellular canals in dicotyledonous woods. J. For. **19,** 255–66; 1921.

1788. —— Cocobolo. Trop. Woods, **1,** 6; 1925.

1789. —— Lapachol. Trop. Woods, **1,** 7–8; 1925.

1790. —— Secretory cells in dicotyledonous woods. Trop. Woods, **1,** 9–12; 1925.

1791. —— Lecythidaceae. Trop. Woods, **1,** 13; 1925.

1792. —— *Schizolobium*: A promising source of pulpwood. Trop. Woods, **2,** 2–5; 1925.

1793. —— Pits with cribriform membranes. Trop. Woods, **2,** 10–13; 1925.

1794. —— Montanoa. Trop. Woods, **2,** 13; 1925.

1795. —— The Chinese 'Pau Hoi'. Trop. Woods, **3,** 1; 1925.

1796. —— African Zebra wood and 'Bubinga'. Trop. Woods, **3,** 2–3; 1925.

1797. —— Colombian 'Nato'. Trop. Woods, **3,** 3–4; 1925.

1798. —— *Jacaranda copaia* in British Guiana. Trop. Woods, **3,** 6–8; 1925.

1799. —— Cystoliths in wood. Trop. Woods, **3,** 10–12; 1925.

1800. —— Spiral tracheids and fiber-tracheids. Trop. Woods, **3,** 12–16; 1925.

1801. —— Occurrence of intercellular canals in dicotyledonous woods. Trop. Woods, **4,** 17–20; 1925.

1802. —— Gum ducts in Lecythidaceae. Trop. Woods, **5,** 14; 1926.

1803. —— Some *Ilex* woods without spiral elements. Trop. Woods, **8,** 9; 1926.

1804. —— The wood of *Saurauia villosa* de Candolle. Trop. Woods, **8,** 11–13; 1926.

1805. Record, S. J. The wood of *Krugiodendron ferreum* (Vahl.) Urban. Trop. Woods, **8,** 11–13; 1926.
1806. —— The wood of *Koeberlinia spinosa* Zuccarini. Trop. Woods, **8,** 15–17; 1926.
1807. —— Radial canals in *Poupartia*. Trop. Woods, **9,** 7; 1927.
1808. —— A new species of *Mollia* of British Guiana. Trop. Woods, **9,** 8–10; 1927.
1809. —— Occurrence of 'ripple marks' in woods. Trop. Woods, **9,** 13–18; 1927.
1810. —— The wood of *Tapura cubensis* (Poepp. & Endl.) Grisebach. Trop. Woods, **9,** 18–19; 1927.
1811. —— Large radial canals in *Couma*. Trop. Woods, **10,** 7; 1927.
1812. —— Note on 'ripple marks' in Compositae. Trop. Woods, **10,** 54; 1927.
1813. —— The butterfly tree of British Honduras. Trop. Woods, **1,** 4; 1927.
1814. —— More woods of Araliaceae with radial canals. Trop. Woods, **11,** 9; 1927.
1815. —— The wood of *Tetrapodenia glandifera* Gleason. Trop. Woods, **11,** 22–4; 1927.
1816. —— Panama 'orey' wood and related species. Trop. Woods, **12,** 6–12; 1927.
1817. —— Gum canals in *Elaeagnus*. Trop. Woods, **12,** 21; 1927.
1818. —— Occurrence of calcium carbonate deposits in woods. Trop. Woods, **12,** 22–6; 1927.
1819. —— The 'Longotra' of Madagascar classified. Trop. Woods, **13,** 1–2; 1928.
1820. —— 'Pink Ivory' wood. Trop. Woods, **13,** 4–5; 1928.
1821. —— More about the Chinese 'Pau-Hoi'. Trop. Woods, **13,** 5–6; 1928.
1822. —— Is *Maba* distinct from *Diospyros*? Trop. Woods, **13,** 6; 1928.
1823. —— The 'Palo Prieto' of West Central Mexico. Trop. Woods, **14,** 8–12; 1928.
1824. —— Various kinds of Chinese 'Pau Hoi'. Trop. Woods, **15,** 13; 1928.
1825. —— Walnut woods—true and false. Trop. Woods, **18,** 4–29; 1929.
1826. —— The West African Abachi, Ayous or Samba (*Triplochiton scleroxylon*). Trop. Woods, **18,** 43–54; 1929.
1827. —— Note on the wood of *Pseudocopaiva*. Trop. Woods, **20,** 28–9; 1929.
1828. —— Fresh wood of *Triplochiton* is malodorous. Trop. Woods, **20,** 19; 1930.
1829. —— Note on the wood of *Celtis hottlei*. Trop. Woods, **20,** 21–2; 1930.
1830. —— No oil cells in *Physocalymma*. Trop. Woods, **20,** 23; 1930.
1831. —— Note on the wood of *Inga Stevensonii*. Trop. Woods, **23,** 7; 1930.
1832. —— The field of wood anatomy. Emp. For. J. **10,** 5–6; 1931.
1833. —— The Rudolph Block collection of walking sticks. J. N.Y. bot. Gdn. **32,** 353–60; 1931.
1834. —— Intercellular canals in Liberian woods. Trop. Woods, **29,** 13; 1932.
1835. —— Formation of 'stone' in the wood of *Chlorophora excelsa*. Trop. Woods, **29,** 33; 1932.
1836. —— Notes on new species of Brazilian woods. Trop. Woods, **31,** 22–9; 1932.
1837. —— Woods of the Ericales, with particular reference to *Schizocardia*. Trop. Woods, **32,** 11–14; 1932.
1838. —— The wood of *Gleasonia duidana*. Trop. Woods, **32,** 18–20; 1932.
1839. —— West African Avodiré (*Turraeanthus africana*). Trop. Woods, **25,** 1–9; 1931.
1840. —— The wood of *Escallonia tortuosa*. Trop. Woods, **26,** 12–13; 1931.
1841. —— Brazilian Kingwood (*Dalbergia cearensis*). Trop. Woods, **28,** 1–3; 1931.
1842. —— The woods of *Rhabdodendron* and *Duckeodendron*. Trop. Woods, **33,** 6–10; 1933.
1843. —— *Identification of the timbers of temperate North America*. New York, pp. 196; 1934.
1844. —— Role of wood anatomy in taxonomy. Trop. Woods, **37,** 1–9; 1934.
1845. —— Note on the classification of *Goethalsia*. Trop. Woods, **40,** 18; 1934.
1846. —— Note on the wood of *Paramachaerium*. Trop. Woods, **41,** 7; 1935.

1847. RECORD, S. J. Note on *Goethalsia* (Tiliaceae). Trop. Woods, **42,** 21; 1935.

1848. —— Note on the wood of *Cephalohibiscus.* Trop. Woods, **44,** 21; 1935.

1849. —— Some problems for the wood anatomist. Trop. Woods, **44,** 26–30; 1935.

1850. —— The woods of *Hymenolobium.* Trop. Woods, **47,** 7–10; 1936.

1851. —— Classifications of various anatomical features of dicotyledonous woods. Trop. Woods, **47,** 12–27; 1936.

1852. —— Importance of the study of wood anatomy. Rodriguésia, **11,** 319–22; 1937.

1853. —— The American woods of the Orders Celastrales, Olacales and Santalales. Trop. Woods, **53,** 11–38; 1938.

1854. —— The American woods of the family Euphorbiaceae. Trop. Woods, **54,** 7–40; 1938.

1855. —— American woods of the family Loganiaceae. Trop. Woods, **56,** 9–13; 1938.

1856. —— American woods of the family Rhamnaceae. Trop. Woods, **58,** 6–24; 1939.

1857. —— American woods of the family Bombacaceae. Trop. Woods, **59,** 1–20; 1939.

1858. —— American woods of the family Sapotaceae. Trop. Woods, **59,** 29–51; 1939.

1859. —— American woods of the family Anacardiaceae. Trop. Woods, **60,** 11–45; 1939.

1860. —— Some new names for tropical American trees of the family Leguminosae. Trop. Woods, **63,** 1–6; 1940.

1861. —— American woods of the family Theaceae. Trop. Woods, **70,** 23–33; 1942.

1862. —— American timbers of the genera *Dalbergia* and *Machaerium.* Trop. Woods, **72,** 1–11; 1942.

1863. —— The woods of *Daubentonia.* Trop. Woods, **72,** 15–16; 1942.

—— Keys to American woods:
1864. I. Ring-porous woods.
1865. II. Pores in ulmiform or wavy tangential arrangement.
1866. III. Pores in flame-like or dendritic arrangement.
Trop. Woods, **72,** 19–35; 1942.
1867. IV. Vessels virtually all solitary.
1868. V. Vessels with spiral thickenings.
Trop. Woods, **73,** 23–42; 1943.
1869. VI. Vessels with scalariform perforation plates.
1870. VII. Vessels with very fine pitting.
Trop. Woods, **74,** 17–43; 1943.
1871. IX. Woods with conspicuous rays. Trop. Woods, **75,** 8–26; 1943.
1872. X. Woods with storied structure. Trop. Woods, **76,** 32–47; 1943.
1873. XI. Woods with resin or gum ducts.
1874. XII. Parenchyma reticulate.
Trop. Woods, **77,** 18–38; 1944.
1875. XIII. Woods with septate fibers. Trop. Woods, **78,** 35–45; 1944.
1876. XIV. Dicotyledonous woods with xylem rays virtually all uniseriate. Trop. Woods, **79,** 25–34; 1944.
1877. XV. Fibers with conspicuous bordered pits.
1878. XVI. Woods with oil (or similar) cells.
Trop. Woods, **80,** 10–15; 1944.
For XVII to XX *see under* HESS, R. W.

1879. —— Miscellaneous notes on tropical American woods. Trop. Woods, **79,** 1–5; 1944.

1880. —— Notes on tropical timbers. Trop. Woods, **80,** 1–6; 1944.

1881. RECORD, S. J. Notes on tropical timbers. Trop. Woods, **81,** 2–5; 1945.

1882. RECORD, S. J., and CHATTAWAY, M. M. List of anatomical features used in classifying dicotyledonous woods. Trop. Woods, **57,** 11–16; 1939.

1883. RECORD, S. J., and GARRATT, G. A. *Cocobolo.* Bull. Yale Sch. For., No. 8, pp. 42; 1923.

1884. —— *Boxwoods.* Bull. Yale Sch. For., No. 14, pp. 81; 1925.

1885. RECORD, S. J., and HESS, R. W. Aids in identifying American timbers of the Order Malvales. Trop. Woods, **51,** 1–10; 1937.

1886. —— *Timbers of the New World.* New Haven, pp. 640; 1943.

1887. —— American woods of the family Moraceae. Trop. Woods, **61,** 11–54; 1940.

1888. —— American timbers of the family Bignoniaceae. Trop. Woods, **63,** 9–38; 1940.

1889. —— American woods of the family Rutaceae. Trop. Woods, **64,** 1–28; 1941.

1890. —— American woods of the family Verbenaceae. Trop. Woods, **65,** 4–21; 1941.

1891. —— American timbers of the Mahogany family. Trop. Woods, **66,** 7–33; 1941.

1892. —— American woods of the family Boraginaceae. Trop. Woods, **67,** 19–33; 1941.

1893. —— American timbers of the family Lauraceae. Trop. Woods, **69,** 7–33; 1942.

1894. RECORD, S. J., and MELL, C. D. *Timbers of tropical America.* New Haven, pp. 610; 1924.

1895. REED, E. L. Extra-floral glands of *Ricinus communis.* Bot. Gaz. **76,** 102–6; 1923.

1896. —— Anatomy, embryology and ecology of *Arachis hypogea.* Bot. Gaz. **78,** 289–310; 1924.

1897. REED, H. S. The density of stomata in citrus leaves. J. Agric. Res. **43,** 209–22; 1931.

1898. REED, T. On the anatomy of some tubers. Ann. Bot. Lond. **24,** 537–48; 1910.

1899. REEVE, R. M. Structure and growth of the vegetative shoot apex of *Garrya elliptica* Dougl. Amer. J. Bot. **29,** 697–711; 1942.

1900. —— Comparative ontogeny of the inflorescence and the axillary vegetative shoot in *Garrya elliptica* Dougl. Amer. J. Bot. **30,** 608–19; 1943.

1901. —— Structural composition of the sclereids in the integument of *Pisum sativum* L. Amer. J. Bot. **33,** 191–204; 1946.

1901A. REHDER, A. *Manual of cultivated trees and shrubs.* New York, pp. 930; 1940.

1902. —— *Schisandra* Michaux, nomen genericum conservandum. J. Arnold Arbor. **25,** 129–31; 1944.

1903. —— Moraceae, Hippocastanaceae et Vitaceae. Nomina conservanda. J. Arnold Arbor. **26,** 277–9; 1945.

1904. REHFOUS, L. Les stomates des Celastraceae. Bull. Soc. bot. Genève, Sér. 2, **6,** 13–8; 1914. *See* Just's Jber., Pt. 1, 517; 1915.

1905. —— Les stomates du *Thea sinensis* et une nouvelle méthode pour reconnaître les falsifications du thé. Bull. Soc. bot. Genève, Sér. 2, **8,** 24–8; 1916. *See* Just's Jber. 768; 1916.

1906. —— Sur la formation de periderme chez *Crassula falcata.* Bull. Soc. bot. Genève, Sér. 2, **14,** 63–9; 1922.

1907. REICHE, K. Die physiologische Bedeutung des anatomischen Baues der Crassulaceen. Mit einem Anhang: Zur Kenntnis von *Senecio praecox* DC. Flora, Jena, **14,** 249–61; 1921.

1908. —— Beiträge zur Kenntnis der Gattung *Fouquiera.* Bot. Jb. **57,** 287–301; 1922.

1909. —— Zur Kenntnis des Dickenwachstums der Opuntien. Naturw. Waschr., N.F. **21,** 33–40; 1922. *See* Just's Jber. 599; 1922.

1910. REICHE, K. Entwicklung, Bau und Leben der *Euphorbia radians* Benth., einer knollen-tragenden Art. Flora, Jena, **116,** 259–69; 1923.

1911. —— Die Ausscheidung von Gummischleim durch flachsprossige Opuntien in Mexiko. Notizbl. bot. Gart. Berl. **8,** 601–13; 1923. *See* Just's Jber., Pt. 1, 696; 1923.

1912. REINDERS, E. Fiber-tracheids, libriform wood fibers, and systematics in wood anatomy. Trop. Woods, **44,** 30–5; 1935.

1913. RENDLE, B. J. 'Paaj' dermatitis produced by Red Quebracho. Trop. Woods, **17,** 7–8; 1929.

1914. —— Wood anatomy as a link between botany and forestry. Nature, Lond. **130,** 3292. 834–6; 1932.

1915. —— The growth and quality of English oak. Forestry, **10,** 38–46; 1936.

1916. —— *Variation in wood anatomy.* Proc. 6th Internat. Bot. Congress, pp. 228; 1936.

1917. —— *The growth and structure of wood.* For. Prod. Res. Rec., No. 21; 1937.

1918. —— *Commercial mahoganies and allied timbers.* Bull. For. Prod. Res. Lond., No. 18, pp. 46; 1937.

1919. —— Gelatinous wood fibres. Trop. Woods, **52,** 11–19; 1937.

1920. —— *The identification of timbers.* For. Prod. Res. Leaflet, No. 34, 1944.

1921. —— On the taxonomic value of the anatomical structure of the vegetative organs of the dicotyledons. III. The role of wood anatomy in the practical identification of commercial timbers. Proc. Linn. Soc. Lond. **155,** 218–21; 1944.

1922. RENDLE, B. J., and CLARKE, S. H. The problem of variation in the structure of wood. Trop. Woods, **38,** 1–8; 1934.

1923. —— The diagnostic value of measurements. Trop. Woods, **40,** 27–37; 1934.

1924. RENNER, O. Über die Epidermis der Blätter von *Hakea* und über Gewebeverschiebung beim Streckungswachstum. Beih. bot. Zbl. **26,** 1. 159–87; 1910.

1925. REULE, H. Vergleichend-anatomische Untersuchung in der Gattung *Mesembrianthemum* L. Flora, Jena, N.S. **31,** 400–24; 1937.

1926. REYES, L. J. Fiber studies of Philippine Dipterocarps. J. For. **19,** 97–104; 1921.

1927. —— Woods of the Philippine Dipterocarps. Philipp. J. Sci. **22,** 291–344; 1923.

1928. —— Woods suitable for acid containers. Makiling Echo (Laguna, P.I.), **7,** 26–8; 1928.

1929. —— *Philippine woods.* Tech. Bull. Dep. Agric. Comm., Manila, No. 7, 1938.

1930. REYNOLDS, M. E. Development of the vascular network in the node of *Ricinus communis.* Amer. J. Bot. **28,** 728; 1941.

1931. —— Development of the node in *Ricinus communis.* Bot. Gaz. **104,** 167–70; 1942.

1932. RIBSTEIN, W. Zur Kenntnis der im alten Ägypten verwendeten Hölzer. Bot. Arch. **9,** 194–209; 1925.

1933. RICHTER, A. A Marcgraviaceae néhány új alakjáról, a származás és az összehasonlító alkattan alapján. Math. term. Értesítő **34,** 5. 8–83: 1916. *See* Bot. Zbl. **140,** 159; 1919.

1934. RICHTER, A. A. A case of formation of adventitious cambial rings in the stem of the common lime tree. C. R. Acad. Sci. U.R.S.S., N.S. **22,** 274–76; 1939.

1935. RIDLEY, H. N. *Firmiana* and *Erythropsis.* Kew Bull. No. 5, 214–17; 1934.

1936. RIEDL, H. Bau und Leistungen des Wurzelholzes. Jb. wiss. Bot. **85,** 1–75; 1937.

1937. RIERA, P. F. *Primera contribución al conocimiento de las maderas de la Guinea continental española.* Madrid, pp. 251; 1944.

1938. RIKLI, M. Über *Cassiope tetragona* (L.) D. Don. Bot. Jb. Festband, **50,** 268–77; 1914. *See* Just's Jber., Pt. 1, 892; 1914.

1939. Rinde, A. *Margyracaena Skottsbergii.* En anatomisk undersökning av en släkthybrid. Acta Hort. Göteborg, **13,** 255–79; 1939.

1940. Ritter, N. Histology of *Astragalus mollissimum.* Kans. Univ. Sci. Bull. **10,** 197–208; 1917. *See* Just's Jber., Pt. 1, 248; 1920.

1941. Ritter, W. *Beiträge zur Diagnose kleinster Mengen berindeten Holzes in zerkleinertem und pulverisiertem Zustande.* Hamburg, pp. 70; 1934.

1942. Ritterhausen, P. *Anatomisch-systematische Untersuchung von Blatt und Axe der Acalypheen.* Thesis, Erlangen, pp. 123; 1892.

1943. Rivett, M. F. The anatomy of *Rhododendron ponticum* L. and of *Ilex aquifolium* L. in reference to specific conductivity. Ann. Bot. Lond. **34,** 525–50; 1920.

1944. —— The root tubercles in *Arbutus unedo.* Ann. Bot. Lond. **38,** 661–77; 1924.

1945. Rivière, S. Étude anatomique de quelques plantes à évolution vasculaire très accélérée. Rev. gén. Bot. **102,** 49–74; 1940.

1946. Rohde, H. Über die kontraktilen Wurzeln einiger Oxalidaceen. Bot. Arch. **22,** 463–532; 1928.

1947. Roncagliolo, M. Descrizione anatomica e comparata degli organe epigei di cinque specie di mimosa. Malpighia, **28,** 435–56; 1920.

1948. Rosen, F. Die biologische Stellung der abessinischen Baumlobelie (*Lobelia rhynchopetalum* (Hochst.) Hemsl.). Beitr. Biol. Pfl. **10,** 265–98; 1910.

1949. Rosengart-Famel, Y. Étude botanique, chemique et pharmacodynamique des diverses espèces des genres *Anabasis* et *Haloxylon.* Trav. Lab. Mat. méd. Paris, **28,** pp. 135; 1937.

1950. Rosenkranz, F. Ein Beitrag zur Blattanatomie der Gattung *Plantago* L. Öst. bot. Z. **75,** 121–4; 1926.

1951. Rosenthal, K. *Daphniphyllaceae* in Engler's *Das Pflanzenreich,* iv. 147*a*; 1919.

1952. —— *Daphniphyllaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.,* Auf. 2, 19C; 1931.

1953. Rosenthaler, L. Pharmacognosy notes. (*Cinchona* barks.) Amer. J. Pharm. **101,** 650–4; 1929.

1954. —— Über Wurzelrinden der Chinchonen. ApothZtg. Berl. 1914. *See* Just's Jber., Pt. 1, 898; 1914.

1955. Rosenthaler, L., and Kiene, K. Über eine chinesische Rhabarberwurzel. Ber. dtsch. pharm. Ges. **24,** 234–43; 1914. *See* Just's Jber., Pt. 1, 898; 1914.

1956. Roshardt, P. A. Schwimm- und Wasserblätter von *Nymphaea alba* L. Ber. dtsch. bot. Ges. **33,** 499–507; 1915.

1957. —— Zahl und Verteilung der Spaltöffnungen in ihrer Abhängigkeit vom Licht beobachtet am Blatt von *Nymphaea alba* L. Ber. schweiz. bot. Ges. xxii–xxv; 1922.

1958. Ross, H. Der anatomische Bau der mexikanischen Kautschukpflanze 'Guayule', *Parthenium argentatum* Gray. Ber. dtsch. bot. Ges. **26A,** 248–63; 1908.

1959. —— Adventivblättchen auf Melastomaceenblättern verursacht durch parasitisch lebende Älchen. Ber. dtsch. bot. Ges. **30,** 346–61; 1912.

1960. Rothlin, E. Contribución al estudio de los *Aspidosperma.* Trab. Inst. Bot. Farmacol. B. Aires, **38,** pp. 128; 1918. *See* Bot. Jb. **56,** 31; 1920/1.

1961. Rouhier, A. Monographie du Peyotl *Echinocactus Williamsii* Lem. Trav. Lab. Mat. méd. Paris, **17,** 341; 1926. *See* Just's Jber., Pt. 2, 461; 1926.

1962. Rousseau, D. Contribution à l'anatomie comparée des Piperacées. Arch. Inst. bot. Univ. Liége, **7,** pp. 45; 1928. *See* Just's Jber., Pt. 1, 948; 1927.

1963. Rousseau, J. Étude de quelques espèces des genres *Malva* et *Lavatera.* Trav. Lab. Mat. méd. Paris, **16,** pp. 112; 1925.

1964. Rowlee, W. W. Tropical trees with light-weight wood. N.Y. Bot. Gdn. 75–8; 1921.

1965. Rudenskaja, V. J. Anatomical premises for breeding large-rooted forms of kok-saghys. C. R. Acad. Sci. U.R.S.S., n.s. **20,** 7–8, 617–20; 1938.

1966. Rudolph, K. Zur Kenntnis des anatomischen Baues der Blattgelenke bei den Menispermaceen. Ber. dtsch. bot. Ges. **27,** 411–21; 1909.

1967. Ruhland, W. Untersuchungen über die Hautdrüsen der Plumbaginaceen. Ein Beitrag zur Biologie der Halophyten. Jb. wiss. Bot. **55,** 409–98; 1915.

1968. Rusby, H. H. The value and limitations of histology in vegetable taxonomy. Proc. Internat. Cong. plant Sci. **2,** 1356–60; (1926) 1929.

1969. Russell, A. M. A comparative study of *Floerkea proserpinacoides* and allies. Contr. bot. Lab. Univ. Pa. **4,** 401–17; 1919.

1970. —— The macroscopic and microscopic structure of some hybrid Sarracenias compared with that of their parents. Contr. bot. Lab. Univ. Pa. **5,** 1–41; 1919.

1971. Russell, W. Sur la présence de sclérites dans les folioles d'une Légumineuse Césalpiniée. C. R. Ass. Fr. Av. Sci. **53,** 427–8; 1929. *See* Bull. Soc. bot. Fr. **78,** 122; 1931.

1972. —— Note sur la structure de la racine de *Derris elliptica.* Rev. Bot. appl. **17,** 539–40; 1937.

1973. —— Étude anatomique de la tige et de la feuille de *Millettia barteri.* Rev. Bot. appl. **17,** 746–8; 1937.

1974. Russell, W., and Hédin, L. Nouvelles Légumineuses-Césalpiniées Africaines à l'appareil sécréteur. C. R. Acad. Sci. Paris, **188,** 880–1; 1929.

1975. Rutiewicz, B. *Recherches anatomiques sur l'Asarum europaeum.* Thesis, Grenoble, 1921. *See* Just's Jber., Pt. 2, 81; 1921.

1976. Saber, A. H. Variation of the epidermal area in senna leaves. Quart. J. Pharm. **7,** 161–6; 1934.

1976a. Sabet, Y. S. Bacterial nodules in the Zygophyllaceae. Nature, Lond. **157,** 3994. 656–7; 1946.

1977. Sabnis, T. S. The physiological anatomy of the plants of the Indian desert. J. Indian bot. Soc. **1,** 42 and 65–83; 1919. **1,** 2. 97–109; 1919. **1,** 4. 97–113; 1919. **1,** 6–7; 1920. **1,** 33–43; 1920. **1,** 65–84; 1920. **1,** 183–205; 1920. **1,** 237–46; 1920. **1,** 277–95; 1920. **2,** 1–19; 1931. **2,** 61–79; 1921. **2,** 93–115; 1921. **2,** 157–73; 1921.

1978. Saint-Laurent, J. de. Études sur les caractères anatomiques sur bois d'Algérie. Bull. Sta. Rech. for., Algér. **1,** 241–55; 1926.

1979. —— Études sur les caractères anatomiques du bois et du liber secondaire dans les essences du Sahara et particulièrement du Hoggar. Bull. Sta. Rech. for., Algér. **2,** 1–60; 1932.

1980. —— Étude anatomique des rameaux chez les essences forestières d'Algérie avec quelques observations sur les modifications amenées par l'âge. Bull. Sta. Rech. for., Algér. **2,** 61–201; 1932.

1981. —— Contribution à l'étude anatomique de la plantule de quelques essences forestières Nord-Africaines. Bull. Sta. Rech. for., Algér. **2,** 497–581; 1938.

1982. Sakisaka, M., and Suehiro, Y. Notes on the development of the star hairs of *Elaeagnus.* Bot. Mag. Tokyo, **43,** 117–21; 1929. *See* Jap. J. Bot. **4,** 102; 1928/9.

1983. Salisbury, E. J. The extra-floral nectaries of the genus *Polygonum.* Ann. Bot. Lond. **23,** 229–41; 1909.

1984. —— Monocotyledonous features of the Ranunculaceae with special reference to the floral structure. Rept. Brit. Ass. Advancement Science, 336; 1919.

1985. —— On the causes and ecological significance of stomatal frequency with special reference to woodland flora. Philos. Trans. Roy. Soc. B, **217,** 1–65; 1927.

1986. Santos, J. K. A pharmacognostical study of *Chenopodium ambrosioides* Linn. from the Philippines. Philipp. J. Sci. **28,** 529–42; 1925.

1987. —— Histological study of the bark of *Alstonia scholaris* R. Brown from the Philippines. Philipp. J. Sci. **31,** 415–25; 1926.

1988. —— A pharmacognostical study of *Datura alba* Nees and *Datura fastuosa* Linnaeus from the Philippines. Philipp. J. Sci. **32,** 275–96; 1927.

1989. SANTOS, J. K. Stem and leaf structure of *Tinospora Rumphii* Boerlage and *Tinospora reticulata* Miers. Philipp. J. Sci. **35**, 187–204; 1928.

1990. —— Histological and microchemical studies on the bark and leaf of *Artabotrys suaveolens* Blume from the Philippines. Philipp. J. Sci. **38**, 269–82; 1929.

1991. —— Leaf and bark structure of some cinnamon trees, with special reference to the Philippine species. Philipp. J. Sci. **43**, 305–65; 1930.

1992. —— Anomalous stem structure in *Archangelisia flava* and *Anamirta cocculus* from the Philippines. Philipp. J. Sci. **44**, 385–407; 1931.

1993. —— The laticiferous vessels and other anatomical structures of *Excoecaria agallocha*. Philipp. J. Sci. **47**, 295–304; 1932.

1994. —— *Strophanthus comingii* A. DC. Rev. filipina Med. **30**, 365; 1939. *See* Quart. J. Pharm. **13**, 84; 1940.

1995. SARAN, A. B. On some anatomical deformities in the root tissue of *Hibiscus esculentus* Linn. brought about by the infection of eel-worms and their bearing on the growth of the plant. J. Indian bot. Soc. **13**, 197–9; 1934.

1996. SARKANY, S. Über Entwicklung und Funktion des interfaszikularen Kambiums bei *Ricinus communis*. Jb. wiss. Bot. **82**, 625–56; 1936.

1997. SATAKE, Y. Systematic and anatomical studies on some Japanese plants. I. Systematic importance of spodograms in the Urticales. J. Fac. Sci. Tokyo Univ. **3**, 485–511; 1931.

1998. SATINA, S., and BLAKESLEE, A. F. Periclinal chimeras in *Datura stramonium* in relation to the development of leaf and flower. Amer. J. Bot. **28**, 862–71; 1941.

1999. SATINA, S., BLAKESLEE, A. F., and AVERY, A. G. Demonstration of the three germ layers in the shoot apex of *Datura* by means of induced polyploidy in periclinal chimeras. Amer. J. Bot. **27**, 895–905; 1940.

2000. SAWYER, W. H., Jun. Stomatal apparatus from the cultivated cranberry *Vaccinium macrocarpon*. Amer. J. Bot. **19**, 508–13; 1932.

2001. SAX, K., and ABBE, E. C. Chromosome numbers and the anatomy of the secondary xylem in the Oleaceae. J. Arnold Arbor. **13**, 37–48; 1932.

2002. SAX, K., and KRIBS, D. A. Chromosomes and phylogeny in Caprifoliaceae. J. Arnold Arbor. **11**, 147–52; 1930.

SAYEEDUD-DIN, M. Some common Indian herbs with notes on their anatomical characters:

2003. I. *Sesamum laciniatum* Klein. J. Bombay nat. Hist. Soc. **41**, 113–15; 1939.

2004. II. *Herpestis Monniera* H.B. & K. J. Bombay nat. Hist. Soc. **41**, 321–2; 1939.

2005. III. *Andrographis echioides* Nees. J. Bombay nat. Hist. Soc. **41**, 548–50; 1940.

2006. IV. *Leonotis nepetaefolia* R.Br. J. Bombay nat. Hist. Soc. **41**, 795–7; 1940.

2007. V. *Allmania nodiflora* R.Br. J. Bombay nat. Hist. Soc. **42**, 161–3; 1941.

2008. VI. *Lochnera pusilla* K. Schum. J. Bombay nat. Hist. Soc. **42**, 280–82; 1941.

2009. VII. *Plumbago zeylanica* Linn. J. Bombay nat. Hist. Soc. **42**, 599–601; 1941.

2010. VIII. *Evolvulus alsinoides* Linn. J. Bombay nat. Hist. Soc. **42**, 816–18; 1941.

2011. IX. *Nicotiana plumbaginifolia* Viv. J. Bombay nat. Hist. Soc. **43**, 2. 170–2; 1942.

2012. X. *Ionidium subfruticosum* Geny. J. Bombay nat. Hist. Soc. **43**, 3. 475–7; 1942.

2013. XI. *Heliotropium zeylanicum* Lamk. J. Bombay nat. Hist. Soc. **44**, 2. 244–6; 1943.

2014. XII. *Enicostemma littorale* Bl. J. Bombay nat. Hist. Soc. **46**, 4. 655–7; 1947.

2015. Sayeedud-Din, M., and Abdus Salam. On the anatomy of some of the Urticaceae. J. Bombay nat. Hist. Soc. **43,** 274–6; 1942.

2016. Sayeedud-Din, M., and Moinuddin, M. Anatomical study of *Holmskioldia sanguinea* Retz. (Verbenaceae). J. Indian bot. Soc. **18,** 31–3; 1939.

2017. Sayeedud-Din, M., and Suxena, M. R. On the anatomy of some of the Asclepiadaceae. Proc. nat. Acad. Sci. Wash. **10,** 129–32; 1940.

Scala, A. C. Contribución al estudio histológico de la flora Chileana.

2018. I. *Villaresia mucronata* Ruiz. et Pav. Rev. chil. Hist. nat. **22,** 129–38; 1918. *See* Just's Jber., Pt. 2, 82; 1921.

2019. III. *Peumus Boldo.* Rev. chil. Hist. nat. **23,** 33–9; 1919. *See* Just's Jber., Pt. 2, 82; 1921.

2020. IV. *Latua pubiflora.* Rev. chil. Hist. nat. **24,** 79–87; 1920.

2021. V. *Cryptocarya Peumus* Nees. Rev. chil. Hist. nat. **25,** 225–32; 1921. *See* Just's Jber., Pt. 2, 82; 1921.

2022. VI. *Lomatia obliqua.* Rev. chil. Hist. nat. **28,** 19–25; 1924.

2023. VII. *Solanum tomatilla* Remy. Rev. chil. Hist. nat. **29,** 52–7; 1925.

2024. —— Contribución al conocimiento histológico de la Yerba-Mate y sus falsificaciones. Rev. Mus. La Plata, **26,** 67–165; 1921/2.

2025. —— Contribución al estudio histológico de las maderas chileñas. Rev. chil. Hist. nat. **33,** 257–68; 1929.

2026. Scaramella, P. P. Anatomici dell' *Hylocereus undatus* (Haworth) Britton and Rose. Nuovo G. bot. ital. **45,** 71–7; 1938.

2027. Schellenberg, G. *Beiträge zur vergleichenden Anatomie und zur Systematik der Connaraceen.* Thesis, Zürich, pp. 158; 1910.

2028. —— Über einige Arten der Gattung *Rourea* Aubl. Engler's Bot. Jb. **56,** 21–9; 1920.

2029. —— *Connaraceae* in Engler's *Das Pflanzenreich,* iv. 127; 1938.

2030. Scherffel, A. Die Hydathoden von *Lathraea squamaria* L. und deren epiphytisches Bakterium *Microbacterium Lathreae* mihi. Mag. Tud. Akad. Math. Természett, Értesítő 346–68; 1928. *See* Bot. Zbl., n.s. **17,** 403; 1930.

2031. Schilling, E. Zur Morphologie, Physiologie und diagnostischen Bewertung der Bastfasern von *Cannabis sativa.* Ber. dtsch. bot. Ges. **41,** 121–7; 1923.

2032. —— Über die Faser von *Sophora flavescens.* Mitt. Forsch. Inst. Sorau Leinenindustr. **2,** 144–6; 1921. *See* Just's Jber., Pt. 2, 83; 1921.

2033. Schinz, H. *Amaranthaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.,* Auf., 2, 16c; 1934.

2034. Schloss, H. Zur Morphologie und Anatomie von *Hydrostachys natalensis* Wedd. S. B. Akad. Wiss. Wien, Math.-Naturw. Kl. **122,** i. 339–59; 1913. *See* Just's Jber., Pt. 2, 1094; 1913.

2035. Schmid, W. Morphologische anatomische und entwicklungsgeschichtliche Untersuchungen an *Mesembryanthemum pseudotruncatellum* Berger. Vjschr. naturf. Ges. Zürich, **8,** 70, pp. 96; 1925. *See* Just's Jber., Pt. 2, 463; 1926.

2036. —— Untersuchungen über den Bau der Wurzel und der Sprossachse der Amaranthaceen. Vjschr. naturf. Ges. Zürich, **63,** 1928.

2037. Schmidt, E. Mikrophotographischer Atlas der mitteleuropäischen Hölzer. Schiftenreihe Reichsinst. ausl. kolon. Forstwirtschaft, No. 1, pp. 112; 1941.

2038. Schmidt, H. *Systematisch-anatomische Untersuchungen des Blattes der Campanuloideen.* Thesis, Erlangen, pp. 104; 1904.

2039. Schmidt, O. Chr. *Aristolochiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.,* Auf. 2, 16b; 1935.

2040. Schmidt, W. G. de. Studies on the distribution and volume of wood rays in slippery elm (*Ulmus fulva*). J. For. **20,** 353–62; 1922.

2041. Schmieg, K. Notes on new cabinet woods from Brazil. Trop. Woods, **5,** 1–4; 1926.

2042. Schmucker, Th. Zur Ökologie der Fensterblätter. Planta, **13,** 1–17; 1931.

2043. Schneider, A. *Castella Nicholsoni* Hooker, Simarubaceae, botany, pharmacology and therapy. J. Amer. pharm. Ass. **14,** 201–9; 1925.

2044. Schneider, E. E. Commercial woods of the Philippines: their preparation and uses. Bull. Bur. For. Phil. Is., No. 14, pp. 246; 1916.

2045. Schneider, H. Morphologische und entwicklungsgeschichtliche Untersuchungen an *Thelygonum cynocrambe* L. Flora, Jena, **106,** 1–41; 1914. *See* Just's Jber., Pt. 1, 879; 1914.

2046. —— The anatomy of peach and cherry phloem. Bull. Torrey bot. Cl. **72,** 137–56; 1945.

2047. Schönland, S. Über die Gattung *Augea* Thunb. Bot. Jb. **50** (Festband), 41–6; 1914.

2048. Schulthess, H. *Pharmakognostisch-anatomische und chemische Untersuchungen von Drogen des Genera Geum, Sieversia und Dryas.* Thesis, Zürich, pp. 114; 1945.

2049. Schulz, G. *Scopolia carniolica* Jacquin. Eine botanisch-pharmakognostische Studie. Bot. Arch. **13,** 433–48; 1926. *See* Just's Jber., Pt. 2, 465; 1926.

2050. Schulz, O. E. *Erythroxylaceae* in Engler's *Das Pflanzenreich,* iv. 134; 1907.

2051. —— *Cruciferae-Brassiceae* in Engler's *Das Pflanzenreich,* iv. 105; 1919.

2052. —— *Cruciferae-Sisymbrieae* in Engler's *Das Pflanzenreich,* iv. 105; 1924.

2053. —— *Cruciferae-Draba und Erophila* in Engler's *Das Pflanzenreich,* iv. 105; 1927.

2054. —— *Erythroxylaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.,* Auf. 2, 19A; 1931.

2055 —— *Cruciferae* in Engler and Prantl's *Die natürl. Pflanzenfam.,* Auf. 2, 17B; 1936.

2056. Schürhoff, P. Ozellen und Lichtkondensoren bei einigen Peperomien. Beih. bot. Zbl. **23,** 1. 14–26; 1908.

2057. Schwantes, G. Series of articles on Mesembryanthemum in Mschr. Kakteenk. 1916/22 and in Z. Sukkulentenk. 1923/8.

2058. Schwarz, W. Die Wellung der Gefässbündel bei *Heracleum.* Planta, **2,** 19–26; 1926.

2059. —— Die Entwicklung des Blattes bei *Plectranthus fruticosus* und *Ligustrum vulgare* und die Theorie der Periklinalchimären. Planta, **3,** 499–526; 1927.

2060. Schweidler, J. H. Die Eiweiss- oder Myrosinzellen der Gattung *Arabis* L. nebst allgemeineren Bemerkungen über Cruciferen-Idioblasten. Beih. bot. Zbl. **26,** 1. 423–75; 1910.

2061. —— Über eigentümliche Zellgruppen in den Blättern einiger Cruciferen. Öst. bot. Z. **60,** 275–8; 1910.

2062. —— Beiträge zur systematischen Bedeutung der Cruciferen-Idioblasten. Jber. Staatsgymnas. Cilli. 3–14; 1915/16. *See* Bot. Zbl. **141,** 161; 1919.

2063. Schweiger, J. Vergleichende Untersuchungen über *Sarracenia* und *Cephalotus folicularis* betreffs ihrer etwaigen systematischen Verwandtschaft. Beih. bot. Zbl. **25,** 2. 490–539; 1909.

2064. Schweitzer, I. Adatok a *Dipsacus* genus anatomiai és fejlödestani ismeretéhez (Beiträge zur Anatomie und Entwicklungsgeschichte der Gattung *Dipsacus*). Jb. Egyetemi Természettudományi, pp. 32; 1910. *See* Bot. Zbl. **116,** 482; 1911.

2065. Scott, C. W. *Photographs of the timbers of Burma as seen through a hand lens.* Burma For. Bull., No. 30, pp. 15; 1932.

2066. Scott, D. H. *Zur Entwicklungsgeschichte der gegliederten Milchröhren der Pflanzen.* Thesis, Würzburg, pp. 23; 1881.

2067. Scott, D. H., and Sargant, E. On the pitchers of *Dischidia rafflesiana* Wall. Ann. Bot. Lond. **26,** 244–69; 1893.

2068. Scott, F. M. Differentiation of the spiral vessels in *Ricinus communis.* Bot. Gaz. **99,** 69–79; 1937.

2069. —— Some features of the anatomy of *Fouquiera splendens.* Amer. J. Bot. **19,** 673–8; 1932.

2070. SCOTT, F. M. Contribution to the causal anatomy of the desert willow, *Chilopsis linearis*. Amer. J. Bot. **22,** 333–43; 1935.

2071. —— Distribution of calcium oxalate crystals in *Ricinus communis* in relation to tissue differentiation and presence of other ergastic substances. Bot. Gaz. **103,** 225–46; 1941.

2072. —— Survey of anatomy, ergastic substances and nuclear size in *Echinocystis macrocarpa* and *Cucurbita pepo*. Bot. Gaz. **104,** 394–408; 1943.

2073. —— Cystoliths and plasmodesmata in *Beloperone, Ficus*, and *Boehmeria*. Bot. Gaz. **107,** 3. 372–8; 1946.

2074. SCOTT, L. I., and WHITWORTH, A. B. On a structural peculiarity of the exodermis of the root of *Pelargonium*. Proc. Leeds phil. lit. Soc. **1,** 312–17; 1928.

2075. SCOTT, M. H. Specific gravity studies of S. African grown timber. S. Afr. J. Sci. **23,** 478–85; 1926.

2076. —— Notes on the characteristics and minute structure of thirty woods indigenous to S. Africa. Bull. Dep. For. S. Afr. **20,** 298–317; 1927.

2077. SCOTT, R. M., and BAKER, K. C. Anatomy of Washington navel orange rind in relation to water spot. Bot. Gaz. **108,** 4. 459–75; 1947.

2078. SEELINGER, R. Untersuchungen über das Dickenwachstum der Zuckerrübe (*Beta vulgaris* L.) var. *rapa* Dum. Arb. Biol. Reichsanst. Land- u. Forstw. **10,** 149–94; (1921) 1919. *See* Just's Jber., Pt. 1, 269; 1920.

2078A. SEIBERT, R. J. New names in *Cybistax* and *Tabebuia*. Trop. Woods, **63,** 7–8; 1940.

2079. SENFT, E. Über die sogenannten 'Inklusen' in der *Glyzyrrhiza glabra* L. und über ihre Funktion. Ber. dtsch. bot. Ges. **34,** 710–18; 1916.

2080. SEVERINI, G. Particolarità morfologiche ed anatomiche nelle radici dell' *Hedysarum coronarium* L. Ann. Bot. Roma, **7,** 75–82; 1909. *See* Just's Jber., Pt. 1, 1001; 1909.

2081. —— Sui tubercoli radicali di *Datisca cannabina*. Ann. Bot. Roma, **15,** 29–51; 1922.

2081A. SEWARD, A. C. *Plant life through the ages*. Cambridge, pp. 601, 1931.

2082. SERVETTAZ, G. Monographie des Éléagnacées. Beih. bot. Zbl. **25,** 2. 1–420; 1909.

2083. SHARPLES, A. The laticiferous system of *Hevea brasiliensis* and its protective function. Ann. Bot. Lond. **32,** 247–51; 1918.

2084. SHARPLES, A., and GUNNERY, H. Callus formation in *Hibiscus Rosasinensis* L. and *Hevea brasiliensis* Müll. Arg. Ann. Bot. Lond. **47,** 827–39; 1933.

2085. SHEFFIELD, F. M. L. Value of phloem necrosis in the diagnosis of potato leafroll. Ann. appl. Biol. **30,** 131–6; 1942.

2086. SHELTON, W. E. Plant response to the dry phases of the climate of S.W. Western Australia. J. roy. Soc. W. Aust. **19,** 13–35; 1932.

2087. SHEPARD, H. B., and BAILEY, I. W. Some observations on the variation in length of coniferous fibers. Proc. Soc. Amer. For. **9,** 522–7; 1914.

2088. SHERFF, E. E. The delimitation of genera from the conservative point of view. Bull. Torrey bot. Cl. **67,** 375–80; 1940.

2089. SHIRLEY, J., and LAMBERT, C. A. The stems of climbing plants. Proc. Linn. Soc. N.S.W. **43,** 600–9; 1918.

2090. —— Cactae or prickly pears. Proc. roy. Soc. Qd. 26, 40–7; 1914.

2091. —— Acacias of South East Queensland. Proc. roy. Soc. Qd. **33,** 39–45; 1921.

2092. —— On *Coprosma Baueri* Endlicher. Proc. roy. Soc. Vict. **35,** 19–23; 1922.

2093. SHORT, G. R. A. The structure of *Coscinium*. Pharm. J. **15,** 156–62; 1925.

2094. —— Quebracho bark. Pharm. J., Ser. 4, **62,** 103–4; 1926.

2095. —— *Berberis aristata* DC. and other species of *Berberis*. A comparative study of the structure of the stems. Pharm. J., Ser. 4, **63,** 189–95; 1926.

2096. SIERSCH, E. Anatomie und Mikrochemie der Hypericumdrüsen. Planta, **3,** 481–9; 1927.

2097. Sifton, H. B. Poison canals of *Cicuta maculata.* Bot. Gaz. **80,** 319–24; 1925.

2098. —— Lysigenous air spaces in the leaf of Labrador tea, *Ledum groenlandicum* Oedr. New Phytol. **39,** 75–9; 1940.

2099. Sim, T. R. *Native timbers of S. Africa.* Mem. Dep. Min. Industr. S. Afr., No. 3, pp. 232; 1921.

2100. Simmler, G. Monographie der Gattung *Saponaria.* Denkschr. Akad. Wiss. Wien, Math.-Naturw. Kl. **85,** 433–509; 1910. *See* Just's Jber., Pt. 2, 1600; 1910.

2101. Simmonds, A. O. The anatomical development of *Lepidium draba.* J. Agric. Res. **57,** 917–28; 1938.

2102. Simmonds, H. African Dipterocarps: an historical and taxonomic survey of the genus *Monotes* A. DC. Bol. Soc. broteriana, **13,** 326; 1939.

2103. Simon, C. Sind die Milchröhren Leitungsorgane? Beih. Bot. Zbl. **35,** 1. 183–218; 1918.

2104. Singh, B. A contribution to the anatomy of *Salvadora persica* L. with special reference to the origin of the included phloem. J. Indian bot. Soc. **23,** 71–8; 1944.

2105. —— An anatomical study of *Tiliacora acuminata* Miers. J. Indian bot. Soc. **24,** 135–46; 1945.

2106. Singh, B. N., Choudri, R. S., and Kapoor, S. L. Structural abnormalities in cotton leaves following exposure of the seed to X-radiation. Ann. Bot. Lond., N.S. **3,** 10. 307–12; 1939.

2107. Sinnott, E. W. Some features of the anatomy of the foliar bundle. Bot. Gaz. **51,** 258–72; 1911.

2108. —— The morphogenetic relationships between cell and organ in the petiole of *Acer.* Bull. Torrey bot. Cl. **57,** 1–20; 1930.

2109. —— The relation of organ size to tissue development in the stem. Amer. J. Bot. **23,** 418–21; 1936.

2110. —— The problem of internal differentiation in plants. American Naturalist, **76,** 253–68; 1942.

Sinnott, E. W., *et al.*

Investigations on the phylogeny of the angiosperms:

2111. I. The anatomy of the node as an aid in the classification of the angiosperms. Amer. J. Bot. **1,** 303–22; 1914.

(and Bailey, I. W.)

2112. III. Nodal anatomy and the morphology of stipules. Amer. J. Bot. **1,** 441–53; 1914.

(and Bailey, I. W.)

2113. IV. The origin and dispersal of herbaceous angiosperms. Ann. Bot. Lond. **28,** 550–96; 1914.

(and Bailey, I. W.)

2114. V. Foliar evidence as to the ancestry and early climatic environment of the angiosperms. Amer. J. Bot. **2,** 1–22; 1915.

2115. Sinnott, E. W., and Bailey, I. W. Anatomical evidence of reduction in certain Amentiferae. Bot. Gaz. **58,** 36–60; 1914.

2116. —— The significance of the 'foliar ray' in the evolution of herbaceous angiosperms. Ann. Bot. Lond. **36,** 523–33; 1922.

2117. Sinnott, E. W., and Bloch, R. Development of the fibrous net in the fruit of various races of *Luffa cylindrica.* Bot. Gaz. **105,** 90–9; 1943.

2118. —— The cytoplasmic basis of intercellular patterns in vascular differentiation. Amer. J. Bot. **32,** 151–6; 1945.

2119. Skipper, E. G. The ecology of the gorse (*Ulex*) with special reference to the growth forms on Hindhead Common. J. Ecol. **10,** 24–52; 1922.

2120. Skottsberg, C. *Myzodendraceae* in Engler's *Das Pflanzenreich,* iv. 68; 1914.

2121. —— Bemerkungen über die Morphologie von *Gunnera macrophylla* Bl. Acta Hort. Göteborg, **5,** 115–26; 1929.

2122. SKOTTSBERG, C. *Myzodendraceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16B; 1935.

2123. —— Observations on Hawaiian violets. Acta Hort. Göteborg, **13**, 451–528; 1940.

2124. —— *Peperomia barteroana* Miq. and *P. tristanensis* Christoph., an interesting case of disjunction. Acta Hort. Göteborg, **16**, 251–88; 1947.

2125. —— The genus *Peperomia* in Chile. Acta Hort. Göteborg, **17**, 1–47; 1947.

2126. SKUTCH, A. F. Peculiarities in the structure of the stem, related to the leaf-sheath in *Hedyosmum*. Ann. Bot. Lond. **41**, 715–30; 1927.

2127. —— A compound leaf with annual increments of growth. Bull. Torrey bot. Cl. **75**, 542–6; 1946.

2128. SKYRME, E. W. Drugs derived from the genus *Plantago*, their botanical sources. Quart. J. Pharm. **8**, 1–12; 1935.

2129. SLEUMER, H. *Olacaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16B; 1935.

2130. —— *Opiliaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16B; 1935.

2131. SMALL, J. The identification value of hairs. Pharm. J., Ser. 4, **36**, 587–91; 1913.

2132. —— Origin and development of the Compositae. New Phytol. **18**, 201–34; 1919.

2133. —— A new adulterant of Buchu. Pharm. J., Ser. 4, **36**, 511; 1913.

2134. SMALL, J., and ADAMS, F. M. J. Yohimbe bark: its history and identification in commerce. Pharm. J., Ser. 4, **54**, 282–5 and 310–13; 1922.

2135. SMITH, A. C. Nomenclatural notes on Araliaceae. Trop. Woods, **66**, 1–6; 1941.

2136. —— The American species of *Drimys*. J. Arnold Arbor. **24**, 1–33; 1943 (A).

2137. —— Taxonomic notes on the Old World species of Winteraceae. J. Arnold Arbor. **24**, 119–64; 1943 (B).

2138. —— Geographical distribution of the Winteraceae. J. Arnold Arbor. **26**, 48–59; 1945.

2139. —— A taxonomic revision of *Trochodendron* and *Tetracentron*. J. Arnold Arbor. **26**, 123–42; 1945.

2140. —— A taxonomic review of *Euptelea*. J. Arnold Arbor. **27**, 175–85; 1946.

2141. SMITH, A. C., and BAILEY, I. W. *Brassiantha*, a new genus of Hippocrateaceae from New Guinea. J. Arnold Arbor. **22**, 389–94; 1941.

2142. SMITH, A. C., and KOCH, M. F. The genus *Espeletia*: a study in phylogenetic taxonomy. Brittonia N.Y. **1**, 479–530; 1935.

2143. SMITH, A. I. Adventitious roots in stem cuttings of *Begonia maculata* and *B. semperflorens*. Amer. J. Bot. **23**, 511–15; 1936.

2144. SMITH, B. E. A taxonomic and morphological study of the genus *Cuscuta*, dodders, in North Carolina. J. Elisha Mitchell Sci. Soc. **50**, 283–302; 1934.

2145. SMITH, E. P. The anatomy and propagation of *Clematis*. Trans. bot. Soc. Edinb. **29**, 17–26; 1927.

2146. —— A comparative study of the stem structure of the genus *Clematis*, with special reference to anatomical changes induced by vegetative propagation. Trans. roy. Soc. Edinb. **55**, 643–64; 1928.

2147. —— Nodal anatomy of some common trees. Trans. bot. Soc. Edinb. **32**, 260–77; 1937.

2148. SMITH, G. E. On the multiperforate plates occurring in the xylem vessels of *Helianthus annuus*. Proc. Leeds phil. lit. Soc. **3**, 106–10; 1935.

2149. SMITH, G. F., and KERSTEN, H. The relation between xylem thickenings in primary roots of *Vicia faba* seedlings and elongation, as shown by soft X-ray irradiation. Bull. Torrey bot. Cl. **69**, 221–34; 1942.

2150. SMITH, H. En morfologisk undersökning öfver *Saxifraga decipiens* Ehrh. × *granulata* L. (*S. Haussknechtii* Engl. & Irmsch.) och dess föräldrar. Svenska bot. Tidskr. **10**, 562–71; 1916.

2151. Smith, H. G. On the crystalline deposit occurring in the timber of the 'Colonial Beech', *Gmelina Leichhardtii*, F. v. M. J. roy. Soc. N.S.W. **46,** 187–200; 1912.

2152. Smith, M. H. Leaf anatomy of the British heaths. Trans. bot. Soc. Edinb. **30,** 198–205; 1930.

2153. Smith, W. W., and Fletcher, H. R. The genus *Primula*. Trans. bot. Soc. Edinb. **34,** 55–158; 1944.

2154. Smith, W. W., and Forrest, G. The sections of the genus *Primula*. J. roy. hort. Soc. **54,** 1–50; 1929.

2155. Snell, R. S., and Pollard, L. H. Anatomy of the Lima bean. Amer. J. Bot. **28,** 727–8; 1941.

2156. Sobels, J. C. Über die Entwicklung und Bewurzelung ruhender Meristeme bei *Bryophyllum calycinum*, *B. crenatum* und *B. proliferum*. Rec. Trav. bot. néerland. **31,** 188–209; 1934.

2157. Soeding, H. Anatomie der Wurzel-, Stengel- und Rübenbildung von Ölraps und Steckrübe. Bot. Arch. **7,** 41–6; 1924.

2158. Solereder, H. *Systematic anatomy of the dicotyledons.* English edition, translated by L. A. Boodle and F. E. Fritsch. Oxford, 2 vols., pp. 1183; 1908.

2159. —— Über die Gattung *Rehmannia*. Ber. dtsch. bot. Ges. **27,** 390–404; 1909.

2160. —— Zur mikroskopischen Pulveranalyse der *Folia Salviae*. Arch. Pharm. Berl. **249,** 123–7; 1911. *See* Just's Jber., Pt. 2, 1051; 1911.

2161. —— Über die Gattung *Hemiboea*. Beih. bot. Zbl. **29,** 2. 117–26; 1912.

2162. —— The glands of *Heterophyllaea pustulata* Hook. f. are not bacterial cavities. S. B. Phys-med. Soz. Erlangen, **43,** 233–6; (1911) 1912. *See* Just's Jber., Pt. 2, 816; 1912.

2163. —— Zur Anatomie der Burseraceen-Gattung *Pachylobus*. Beih. bot. Zbl. **32,** 1. 148–54; 1914.

2164. —— Über die Versetzung der Gattung *Heteranthia* von den Scrophulariaceen zu den Solanaceen. Beih. bot. Zbl. **23,** 2. 113–17; 1915.

2165. —— Zwei Beiträge zur systematischen Anatomie. Bot. Jb. **50** (Suppl.), 578–85; 1914.

2166. Sonntag, P. Die mikroskopische Unterscheidung der Hanf- und Flachsfaser. Ber. dtsch. bot. Ges. **29,** 669–71; 1911.

2167. Sperlich, A. Optisches Verhalten in der Oberseitigen Blattepidermis. S. B. Akad. Wiss. Wien Math.-Naturw. Kl. **120,** 349–78; 1911. *See* Just's Jber., Pt. 2, 1065; 1911.

2167a. —— Die Absorptionsorgane der parasitischen Samenpflanzen in Linsbauer's Handbuch der Pflanzenanatomie, **9,** 2; 1925.

2168. Spiekerkoetter, H. Untersuchungen zur Anatomie und Systematik ostafrikanischer Meliaceen, Burseraceen und Simarubaceen. Bot. Arch. **7,** 274–320; 1924.

2169. Spieth, A. M. Anatomy of the transition region in *Gossypium*. Bot. Gaz. **95,** 2. 338–47; 1933.

2170. Spoerri, W. *Beiträge zur Anatomie des Blattes pharmazeutisch gebräuchlicher Scrophulariaceendrogen.* Thesis, Basel, pp. 60; 1930.

2171. Sporer, H. Die Blattanatomie der Sudafrik *Crassula pyramidalis*. Öst. bot. Z. **65,** 81–101; 1915.

2172. Sprague, T. A. *Taxonomic botany, with special reference to the angiosperms.* From 'The New Systematics', Oxford, 435–54; 1940.

2172a. —— The classification of the dicotyledons. J. Bot. Brit. Foreign, **63,** 9–13 and 105–13; 1925.

2173. Sprague, T. A., and Boodle, L. A. Kokoti (*Anapyxis ealaensis* Sprague). Kew Bull. No. 7, 309–12; 1909.

2174. —— West Indian boxwood (*Casearia praecox* Griseb.). Kew Bull. No. 6, 214–19; 1914.

2175. SPRAGUE, T. A., and METCALFE, C. R. The taxonomic position of *Rhynchocalyx*. Kew Bull. No. 7, 392–4; 1937.

2176. SPRATT, E. R. The morphology of the root tubercles of *Alnus* and *Elaeagnus* and the polymorphism of the organism causing their formation. Ann. Bot. Lond. **26,** 119–28; 1912.

2177. SPRUMONT, G. Étude descriptive de la tige et de la feuille de *Picralima klaineana* Pierre. J. Pharm. Belg. **9,** 821–4; 1927.

2178. STABER, M. J. Notes on the anatomy of *Sesbania macrocarpa* Muhl. Bull. Torrey bot. Cl. **36,** 625–33; 1909.

2179. STADE, H. *Beiträge zur Kenntnis des Hautgewebes von Euphorbia.* Thesis, Kiel, pp. 47; 1911. *See* Just's Jber., Pt. 2, 1050; 1911.

2180. STADLER, H. P. *Die Morphologie und Anatomie von Cnicus benedictus* L. Thesis, Strasbourg, pp. 79; 1908.

2181. STAHEL, G. *Surinam timbers.* Agric. Exp. Sta. Paramaribo, Surinam, pp. 39; *c.* 1945.

2182. STANDLEY, P. S. Brazilian tulipwood. Trop. Woods, **86,** 1–3; 1946.

2183. STANER, P. Les Acajous du Congo Belge. Bull. agric. Congo belge, **34,** 163–245; 1943.

2184. STANFORD, E. E., and VIEHOEVER, A. Chemistry and histology of the glands of the cotton plant, with notes on the occurrence of similar glands in related plants. J. Agric. Res. **13,** 419–35; 1918.

2185. STAPF, O. Akaniaceae. A new family of Sapindales. Kew Bull. No. 9, 378–80; 1912.

2186. —— *Sargentodoxa cuneata* in Curtis's Bot. Mag. **151,** 9111–12; 1926.

2187. STAPF, O., and BOODLE, L. A. *Peglera* and *Nectaropetalum.* Kew Bull. No. 4, 188–91; 1909.

2188. STARR, A. M. Comparative anatomy of dune plants. Bot. Gaz. **54,** 265–305; 1912.

2189. STEARN, W. T. *Epimedium* and *Vancouveria:* a monograph. J. linn. Soc. (Bot.), **51,** 409–535; 1938.

2190. STECKBECK, D. W. The comparative histology and irritability of sensitive plants. Contr. bot. Lab. Univ. Pa. **4,** 185–230; 1919.

2191. STEIGER, E. *Beiträge zur Morphologie der Polygala Senega* L. Thesis, Basel, pp. 76; 1920. Published also in Ber. dtsch. pharm. Ges. **30,** 43–116; 1920. *See* Just's Jber., Pt. 1, 252; 1920.

2192. STEIN, F. Über Ölkörper bei Oenotheraceen. Öst. Bot. Z. **65,** 43–9; 1915.

2193. STEINER-BERNIER, M. Contribution à l'étude du Peyotl (*Echinocactus williamsii* Lem.). Trav. Lab. Mat. méd. Paris, **28,** pp. 70; 1937.

2194. STEPHENS, E. L. The development of the seed coat of *Carica papaya.* Ann. Bot. Lond. **24,** 607–10; 1910.

2195. —— The structure and development of the haustorium of *Striga lutea.* Ann. Bot. Lond. **26,** 1067–76; 1912 (*a*).

2196. —— Note on the anatomy of *Striga lutea* Lour. Ann. Bot. Lond. **26,** 1125–6; 1912 (*b*).

2197. STERN, K. Beiträge zur Kenntnis der Nepenthaceen. Flora, Jena, N.S. **9,** 213–82; 1917.

2198. STEUDE, H. Beiträge zur Morphologie und Anatomie von *Mourera aspera.* Beih. bot. Zbl. **53,** 1. 627–50; 1935.

2199. STEVENSON, N. S. The Honduras rosewood. Trop. Woods, **12,** 1–3; 1927.

2200. STEWART, E. G. Mucilage or slime formation in the cacti. Bull. Torrey bot. Cl. **46,** 157–66; 1919.

2201. STOBER, J. P. A comparative study of winter and summer leaves of various herbs. Bot. Gaz. **63,** 89–109; 1917.

2202. STONE, H. Les Bois utiles de la Guyane française. Ann. Mus. colon. Marseille, **25** (3rd Ser.), 4. 2. 39–145; 5. 3. 3–159; 6. 2. 3–68; 8. 2. 1–98; 1916–22.

2203. STONE, H. *A guide to the identification of our more useful timbers.* Cambridge, pp. 52; 1920.

2204. —— *The adventitious nature of the so-called medullary rays.* Cambridge, pp. 16; 1920.

2205. —— *A text-book of wood.* London, pp. 240; 1921.

2206. STONE, H., and COX, H. A. *A guide to the identification of the more useful timbers of Nigeria.* London, pp. 111; 1922.

2207. STONE, H., and FREEMAN, W. G. *The timbers of British Guiana.* London, pp. 110; 1914.

2208. STOPES, M. C. Petrifications of the earliest European angiosperms. Philos. Trans. Roy. Soc. B., **203**, 75–100; 1912.

2209. STOPES, M. C., and FUJII, K. Studies in the structure and affinities of Cretaceous plants. Philos. Trans. Roy. Soc. B., **201**, 1–90; 1910.

2210. STOUT, A. B. Duplication and cohesion in the main axis in *Cichorium intybus.* Mem. Brooklyn bot. Gard. **1**, 480–5; 1918.

2211. STRACKE, G. J. Der Tee und die Phloroglucin-reaktion. Mikrokosmos, **18**, 213–15; 1925.

2212. STRIGL, M. Der Thallus von *Balanophora* anatomisch-physiologisch geschildert. S. B. Akad. Wiss. Wien **117**, 1127–75; 1908. *See* Just's Jber., Pt. 1, 481; 1908.

2213. STRUCKMEYER, B. E. Structure of stems in relation to differentiation and abortion of blossom buds. Bot. Gaz. **103**, 182–91; 1941.

2214. STÜRM, K. Monographische Studien über *Adoxa Moschatellina* L. Vjschr. naturf. Ges. Zürich, **55**, 391–462; 1910.

2215. SUCKLING, L. A. The leaf anatomy of some trees and shrubs growing on the port hills, Christchurch. Trans. N. Zealand Inst. **46**, 178–88; 1913.

2216. SUDWORTH, G. B., and MELL, C. D. *The identification of important North American oak woods based on a study of the anatomy of the secondary woods.* Bull. U.S. Dep. Agric., No. 102; 1911.

2217. —— *Distinguishing characteristics of North American gum woods.* Bull. U.S. Dep. Agric., No. 103; 1911.

2218. —— *Fustic wood: its substitutes and adulterants.* Circ. U.S. For. Serv., No. 184, pp. 14; 1911.

2219. —— *'Colombian mahogany.' Its characteristics and its use as a substitute for true mahogany.* Circ. U.S. For. Serv., No. 185, pp. 16; 1911.

2220. SUESSENGUTH, K. Über die Gattung *Lennoa.* Ein Beitrag zur Kenntnis exotischer Parasiten. Flora, Jena, **122**, 264–305; 1927. *See* Just's Jber., Pt. 1, 951; 1927.

2221. SUMMERS, F. On the occurrence of Lens-cells in the epidermis of *Mesembryanthemum pseudotruncatellum.* Ann. Bot. Lond. **25**, 1137–45; 1911.

2222. SURGIS, E. Recherches sur les Frankeniaceae. Rev. gén. Bot. **34**, 409–16; 450–62, 499–507; 1922.

2223. SWAIN, E. H. F. A universal index to wood. J. For. **24**, 735–55; 1926.

2224. —— *The timbers and forest products of Queensland.* Brisbane, pp. 500; 1928.

2225. SWINGLE, W. T. *Eremocitrus,* a new genus of hardy, drought resistant citrous fruits from Australia. J. Agric. Res. **2**, 85–100; 1914.

2226. SZE, Y. C. *Illicium religiosum* Siebold, Mang Tsao, a phytochemical study. Amer. J. Pharm. **101**, 550–74; 622–37, 687–716; 1929.

2227. SZTANKOVITS, R. A hazai Carpinusok levelének és termésének histologiája. (Anatomie der Blätter und Früchte der ungarischen *Carpinus*-Arten. With German summary.) Bot. Közl. **11**, 1–13; 1912. *See* Bot. Zbl. **120**, 184–5; 1912.

2228. SZYMKIEWICZ, D. Recherches écologiques sur les plantes des montagnes. Kosmos, Lwów, **51**, 1–34; 1927. *See* Bot. Zbl. N.S. **11**, 281; 1927/8.

Tang, Y. Timber studies of Chinese trees:

2229. I. Timber anatomy of Rhoipteleaceae. Bull. Fan. Inst. Biol. Peking, **3,** 127–31; 1932.

2230. II. Identification of some important hardwoods in northern China by their gross structures. Bull. Fan. Inst. Biol. Peking, **3,** 157–210; 1932.

2231. III. Identification of some important hardwoods of South China by their gross structures. Bull. Fan. Inst. Biol. Peking, **3,** 253–338; 1932.

2232. —— A preliminary study on the identification of the economic woods of China. Sunyatsenia, **3,** 44–64; 1935.

2233. —— Notes on the systematic position of Bretschneideraceae as shown by its timber anatomy. Bull. Fan. Inst. Biol. Peking, **6,** 153–7; 1935.

2234. —— Systematic anatomy of the woods of the Hamamelidaceae. Bull. Fan. Inst. Biol. Peking, n.s. **1,** 8–62; 1943.

2235. Tansley, A. G. Medullary rays and the evolution of the herbaceous habit. New Phytol. **10,** 362–6; 1911.

2236. Tate, P. On the anatomy of *Orobanche hederae* Duby and its attachment to its host. New Phytol. **24,** 284–93; 1925.

2237. Taylor, F. H. Comparative anatomy of the secondary xylem in the Violaceae and Turneraceae (Abstract). Amer. J. Bot. **25,** 20s; 1938.

2238. Taylor, G. C. *Ceanothus americanus* as a hemostatic. A résumé of investigations into the chemistry, pharmacology and clinical use of the drug. Amer. J. Pharm. **99,** 214–32 and 397–407; 1927.

2239. Taylor, R. A. Studies on the genera *Cytisus* and *Genista*. Trans. bot. Soc. Edinb. **32,** 278–86; 1937.

2240. Tellini, G. Ricerche anatomici su *Dianthus arboreus* (*D. aciphyllus* Sieb.). Nuovo G. bot. ital. **46,** 4. 615–42; 1939.

2241. Tenopyr, L. A. On the size and shape of cells in leaves of different forms of the same plant (*Campanula rotundiflora* and *Lobelia erinus*). Bull. Torrey bot. Cl. **45,** 51–76; 1918.

2242. Teschner, H. Die Lauraceen Nordost-Neu-Guineas. Bot. Jb. **58,** 380–440; 1923. *See* Just's Jber., Pt. 1, 681; 1923.

2243. Tetley, U. The secretory system of the roots of the Compositae. New Phytol. **24,** 138–62; 1925.

2244. Tever, N. S. Studies in the flax plant. I. Physiology of growth, stem anatomy and fibre development in the fibre flax. Aust. J. exp. Bio. med. Sci. **20,** 149–60; 1942. *See* Biol. Abstr. **17,** No. 9537; 1943.

2245. Thiel, A. F. Anatomy of the primary axis of *Solanum melongena*. Bot. Gaz. **92,** 407–19; 1931.

2246. —— Anatomy of the transition region of *Helianthus annuus*. J. Elisha Mitchell Sci. Soc. **50,** 268–74; 1934.

2247. Thieme, H. W. Das Bongosiholz und seine Abstammung. Bot. Arch. **26,** 164–223; 1929.

2248. Thierry, A. *Contribution à l'étude anatomique des Chloranthacées.* Thesis, Paris, pp. 164; 1913. *See* Just's Jber., Pt. 2, 1100; 1913.

2249. Thoday, D. On the behaviour during drought of leaves of two Cape species of *Passerina*, with some notes on their anatomy. Ann. Bot. Lond. **35,** 585–601; 1921.

2250. —— On the organisation of growth and differentiation in the stem of the sunflower. Ann. Bot. Lond. **36,** 489–510; 1922.

2251. —— Interpretation of plant structure. Nature, Lond. **144,** 571–5; 1939.

2252. Thompson, H. Stuart. Radical leaves of *Parnassia palustris* and *Valeriana dioica*. New Phytol. **16,** 151–3; 1917.

2253. Thompson, W. P. On the origin of multiseriate rays in dicotyledons. Ann. Bot. Lond. **25,** 1005–14; 1911.

2254. —— The relationships of the different types of angiosperm vessels. Ann. Bot. Lond. **37,** 183–92; 1923.

2255. Thompson, W. P. Independent evolution of vessels in Gnetales and Angiosperms. Bot. Gaz. **65,** 83–90; 1918.

2256. Thompson, W. P., and Bailey, I. W. Are *Tetracenton, Trochodendron* and *Drimys* specialized or primitive types? Mem. N.Y. bot. Gdn. **6,** 27–32; 1916.

2257. Tillson, A. H., and Muller, C. H. Anatomical and taxonomic approaches to subgeneric segregation in American *Quercus.* Amer. J. Bot. **29,** 523–29; 1942.

2258. Timmerman, H. A. *Stramonium* and other species of *Datura*: a comparative study of the structure of their leaves. Pharm. J., Ser. 4, **64,** 735–42; 1927.

2259. —— *Stramonium* and other species of *Datura*: a comparative study of the structure of their seeds. Pharm. J., Ser. 4, **64,** 742–6; 1927.

2260. Timmermans, S. Beiträge zur Kenntnis der Anatomie und des anormalen Dickenwachstums von *Phytocrene macrophylla* Bl. Ann. Jard. bot. Buitenz. **41,** 65–104; 1931.

2261. Tippo, O. Comparative anatomy of the Moraceae and their presumed allies. Bot. Gaz. **100,** 1–99; 1938.

2262. —— The comparative anatomy of the secondary xylem and the phylogeny of the Eucommiaceae. Amer. J. Bot. **27,** 832–38; 1940.

2263. —— A list of diagnostic characteristics for descriptions of dicotyledonous woods. Trans. Illinois Acad. Sci. **34,** 2; 1945.

2264. —— The role of wood anatomy in phylogeny. Amer. Midl. Nat. **36,** 362–72; 1946.

2265. Tison, A. Production anormale de racines adventives. Bull. Soc. linn. Normandie, Sér. 6, **4,** 1–15; 1911.

2266. Tobler, F. Über die Fasern von Samenflachssorten (Beiträge zur Anatomie des Leinstengels I). Faserforschung, **1,** 47–63; 1921.

2267. Tobler, G. Cordia-Bast. Faserforschung, **3,** 161–6; 1923.

2268. Tolle, H. *Beiträge zur vergleichenden Anatomie der Rubiaceen.* Thesis, Göttingen, pp. 63; 1913. *See* Just's Jber., Pt. 2, 1102; 1913.

2269. Tôrres, J. P. de. Estudo do lenho de algumas espécies florestais de Timor. Rev. agron. Lisboa, **29,** 56–86; 1941.

2270. Tortorelli, L. A. Tecnología de Maderas Argentinas. Maderil, **11,** 19–24; 1938.

2271. —— *Maderas argentinas. Estudio xilológico y technológico de las principales especies arbóreas del país.* Buenos Aires, pp. 218; 1940.

2272. —— Estudio xilológico del *Drimys Winteri.* Rev. Fac. Agron. B. Aires, **11,** 42–9; 1944.

2273. —— La disposición estratificada de los elementos leñosos en el 'ibira-ita' (*Muellera Glaziovii*). Pub. Téc. No. 5, Rev. Inst. Bot. Darwinion, **7,** 58–61; 1945.

2274. Trabut, L. Le Tlaia; *Tamarix articulata.* Bull. Sta. Rech. Algér. **1,** 336–49; 1926.

2275. Trapp, G. A study of the foliar endodermis in the Plantaginaceae. Trans. roy. Soc. Edinb. **57,** 523–46; 1933.

2276. Treitel, G.-I. *Beiträge zur Pharmakognosie der Cruciferae. Anatomie des Laubblattes.* Thesis, Basel, pp. 74; 1938.

2277. Trendelenburg, R. *Das Holz als Rohstoff, seine Entstehung, stoffliche Beschaffenheit und chemische Verwertung.* Berlin, pp. 435; 1939.

2278. Treub, M. M. Sur le *Myrmicodia echinata* Gaudich. Ann. Jard. bot. Buitenz. **3,** 129–59; 1883.

2279. Trinkgeld, R. Beiträge zur Morphologie der Vegetations-organe der Cucurbitaceen. Flora, Jena, **116,** 270–95; 1923. *See* Just's Jber., Pt. 1, 698; 1923.

2280. Trochain, J. Note sur l'anatomie de la feuille d'une Asclepiadée: le *Leptadenia lancifolia* Decne. Bull. Soc. bot. Fr. **79,** 28–32; 1932.

2281. Trochain, J., and Dulau, L. Quelques particularités anatomiques d'*Avicennia nitida* (Verbenaceae) de la mangrove ouest-africaine. Trav. Lab. Forest. Toulouse, **3**, Article XIX; 1942.

2282. Troll, W. Über die sogenannten Atemwurzeln der Mangroven. Ber. dtsch. bot. Ges. **48**, 81–99; 1930.

2283. Troll, W., and Dragendorff, O. Über die Luftwurzeln von *Sonneratia* Linn. f. und ihre biologische Bedeutung. Planta, **13**, 311–473; 1931. Summarized by Metcalfe, C. R., in Kew Bull. No. 10, 465–7; 1931.

2284. Trotter, H. *The common commercial timbers of India and their uses*. Calcutta, pp. 234; 1941.

2285. Trülzsch, O. Über die Ursachen der Dorsiventralität der Sprosse von *Ficus pumila* und einigen anderen Pflanzen. Jb. wiss. Bot. **54**, 1–69; 1914.

2286. Trumke, H. *Beiträge zur Anatomie der sukkulenten Euphorbien*. Thesis, Breslau, pp. 91; 1913. *See* Just's Jber., Pt. 2, 1102–3; 1913.

2287. Tubeuf, K. F. von. *Monographie der Mistel*. Berlin, pp. 832; 1923.

2288. Tunman, O. Über den anatomischen Bau der Rhizoma Gelsemii (*Gelsemium sempervirens* Ait.). Pharm. Zentralh. 679–87; 1907. *See* Just's Jber., Pt. 1, 492; 1908.

2289. —— Folia Boldo (*Peumus boldus* Mol.). ApothZtg. Berl., 1908. *See* Just's Jber., Pt. 1, 490; 1908.

2290. —— Microskopisch-pharmacognostische Beiträge zur Kenntnis einiger neuerer Arzneidrogen. Pharm. Zentralh. 159–66; 1908. *See* Just's Jber., Pt. 1, 486; 1908 and Pharm. Zentralh. 219–24; 1908. *See* Just's Jber., Pt. 1, 485; 1908.

2291. —— Zur Anatomie des Holzes und der Wurzel von *Morinda citrifolia* L. mit besonderer Berücksichtigung der mikrochemischen Verhältnisse. Pharm. Zentralh. 1013–17; 1908. *See* Just's Jber., Pt. 1, 488; 1908.

2292. —— Über *Ferula narthex* Boissier, insbesondere über die Sekretgänge dieser Pflanze. Ber. dtsch. bot. Ges. **30**, 245–56; 1912.

2293. —— Über 'Einschlüsse' im Rhizom von Rheum, zugleich ein Beitrag zur Mikrochemie der Oxymethylanthrachinone führenden Pflanzen. Ber. dtsch. bot. Ges. **35**, 191–203; 1917.

2294. Tupper, W. W. An unusual growth ring in *Eucalyptus*. Pap. Mich. Acad. Sci. **13**, 217–19; 1913.

2295. —— Woods with conspicuously large rays. Trop. Woods, **11**, 5–9; 1927.

2296. —— A comparative study of Lauraceous woods. Amer. J. Bot. **14**, 520–4; 1927.

2297. —— Preliminary report on the wood structure of the Flacourtiaceae. Trop. Woods, **38**, 11–14; 1934.

2298. Tupper, W. W., and Bartlett, H. H. A comparison of the wood structure of *Oenothera stenomeres* and its tetraploid mutation *gigas*. Science, **43**, 292; 1916.

2299. Turmel, J. M. À propos de groses souches d'Ombellifères. Bull. Soc. bot. Fr. **91**, 6–9; 1944.

2300. Turner, L. M. Anatomy of aerial roots of *Vitis rotundifolia*. Bot. Gaz. **96**, 367–71; 1934.

2301. Turrell, F. M. Citrus leaf stomata; structure composition, and pore size in relation to penetration of liquids. Bot. Gaz. **108**, 476–83; 1947.

2302. Turrell, F. M., and Klotz, L. J. Density of stomata and oil glands and incidence of water spot in the rind of Washington navel orange. Bot. Gaz. **101**, 862; 1940.

Turrill, W. B. Taxonomy and phylogeny:

2303. Pt. I. Bot. Rev. **8**, 247–70; 1942.

2304. Pt. II. Bot. Rev. **8**, 473–532; 1942.

2305. —— Experimental attacks on species problems. Chron. Bot. **7**, 281–3; 1942.

2306. Turrill, W. B., and Boodle, L. A. A hybrid heath. Kew Bull. No. 9, 378–9; 1911.

2307. Ugrenovic, A. Die Kenntnis des Holzes und seiner Eigenschaften bei den Römern. Forstwissensch. Zbl. **60**, 570–83; 1938.

2308. Ulbrich, E. Monographie der afrikanischen *Pavonia*-Arten nebst Übersicht über die ganze Gattung. Bot. Jb. **57**, 54–184; 1920. *See* Just's Jber., Pt. **1**, 253; 1920.

2309. —— *Basellaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16c; 1934.

2310. —— *Thelygonaceae* (Cynocrambaceae) in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16c; 1934.

2311. —— *Chenopodiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 16c; 1934.

2312. Unger, W. Radix Belladonnae und Radix Sambuci Ebuli. Arch. Pharm. Berl. **263**, 606–11; 1925. *See* Just's Jber., Pt. 2, 469; 1926.

2313. —— Beitrag zur anatomischen Kenntnis der Kräuterdrogen (Folia Plantaginis). Arch. Pharm. Berl. **264**, 754–62; 1926.

2314. Uphof, J. C. T. Biologische Beobachtungen an *Batis maritima*. Öst. bot. Z. **79**, 355–67; 1930.

2315. —— *Sarraceniaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 17b; 1936.

2316. Urcelay, J. C. Contribución al estudio de la adaptación de las plantas para disminuar la transpiración. Estudio anatómico de algunas especies de las stepas españoles. Trab. Mus. Nac. Cienc. nat. Madrid. Bot., Ser. 18, pp. 75; 1923.

2317. Uspensky, E. E. Bestimmung der mittelrussischen Bäume und Gesträuche nach den Elementen des Holzes. Z. f. Torfindustrie, Moscow, n.f. **1–2**, 102–21; 1922.

2318. Van Tieghem, P. Structure et affinitées des Erythroxylacées. Bull. Mus. hist. Nat. **9**, 289; 1903.

2319. —— Sur les canaux à mucilage des Piperées. Ann. Sci. nat. b., Sér. 9, **7**, 117–27; 1908.

2320. Varga, F. Vergleichende anatomische Untersuchung der Gattungen *Succissella* und *Succisa* mit Rücksicht auf die verwandten Gattungen. (Hungarian with German summary.) Bot. Közl. **21**, 32–47; 1923. *See* Just's Jber., Pt. 1, 682; 1923.

2321. —— Die Anatomie des Blattes der *Cephalaria speciosa*. (Hungarian with German summary.) Bot. Közl. **22**, 28–34; 1925. *See* Just's Jber., Pt. 2, 470; 1926.

2322. Varossieau, W. W. Microscopical anatomy of tropical plants. I. Anatomical and microchemical observations on the leaf of *Palaquium gutta*. Ann. Jard. bot. Buitenz. **48**, 3–4. 153–72; 1938.

2323. —— *On the development of the stem and the formation of leaves in Coffea species.* Thesis, Brille, pp. 88; 1940.

2324. —— On the taxonomic position of *Eucommia ulmoides* Oliv. (Eucommiaceae). Blumea, **5**, 1. 81–92; 1942.

2325. —— Waarnemingen over de melksaphoudende elementen van *Eucommia ulmoides* Oliv. Ned. Akad. Wetensch. Afd. Natuur-kunde, **52**, 3. 1–12; 1943.

2326. Vassilchenko, T. T. Über die Bedeutung der Keimungsmorphologie für die phylogenetische Systematik der Blütenpflanzen. Chronica Bot. **7**, 254; 1942.

2327. Vaupel, F. *Cactaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 21; 1925.

2328. Vechot, A. *Études anatomiques sur la tribe des Trifoliées.* Thesis, Paris, pp. 271; 1920.

2329. Vestal, P. A. The significance of comparative anatomy in establishing the relationship of the Hypericaceae to the Guttiferae and their allies. Philipp. J. Sci. **64**, 199–256; 1937.

2330. Vestal, P. A. Wood anatomy as an aid to classification and phylogeny. Chronica bot. **6,** 53–4; 1940.

2331. Vestal, P. A. and Vestal, M. R. The formation of septa in the fiber-tracheids of *Hypericum Androsaemum* L. Leafl. Bot. Mus. Harvard Univ. **8,** 169–88; 1940.

2332. Viehover, A., Ewing, C. O., and Clevenger, J. G. Commercial Viburnum barks and preparations. J. Amer. pharm. Ass. **7,** 944–52; 1918.

2333. Vigne, C., and Record, S. J. *Panda oleosa* Pierre. Trop. Woods, **20,** 14–17; 1930.

2334. Viguier, R. Recherches anatomiques sur la classification des Araliacées. Ann. Sci. nat. b., Sér. 9, **4,** 1–209; 1906.

2335. —— Nouvelles recherches sur les Araliacées. Ann. Sci. nat. b., Sér. 9, **9,** 305–405; 1909.

2336. Vischer, W. Über die Bewegung des Latex in den Latex-gefässen des brasilianischen Kautschukbaumes (*Hevea brasiliensis*). Ber. schweiz. bot. Ges. **32,** xxx; 1923.

2337. —— Über die Konstanz anatomischer und physiologischer Eigenschaften von *Hevea brasiliensis* Müller-Arg. (Euphorbiaceae). Verh. naturf. Ges. Basel, **35,** 1. 174–85; 1923. *See* Just's Jber., Pt. 1, 699; 1923.

2338. Vogl, K. Anatomische Studien über Blatt und Achse der einheimischen *Daphne*-Arten mit besonderer Berücksichtigung der Bastfasern. Progr. Gymnas-Oberhollabrunn, pp. 29; 1910. *See* Just's Jber., Pt. 2, 1590; 1910.

2339. Voigt, A. Verfälschung von Folia Sennae. Angew. Bot. **4,** 295; 1922.

2340. Voss, G. Über Unterschiede im anatomischen Bau der Spaltöffnungen der Laubblätter einiger Dikotylen. Beih. bot. Zbl. **33,** 1. 71–128; 1916.

2341. Vouk, V. Über eigenartige Pneumathoden an dem Stamme von *Begonia vitifolia* Schott. Ber. dtsch. bot. Ges. **30,** 257–62; 1912.

2342. —— Nachtrag zu den Untersuchungen 'Über Guttation und Hydathoden bei *Oxalis*-Arten.' Rad. Jugosl. akad. znanosti Kuj, **215,** 55–8; 1916. *See* Bot. Zbl. **137,** 385; 1918.

2343. Wagner, K. A. Notes on the anomalous stem structure of a species of *Bauhinia.* Amer. Midl. Nat. **36,** 251–6; 1946.

2344. Waldron, R. A. The peanut (*Arachis hypogaea*)—its history, histology, physiology and utility. Contr. bot. Lab. Univ. Pa. **4,** 301–38; 1919. *See* Just's Jber., Pt. 1, 254; 1920.

2345. Walensky, W. *Vergleichend-anatomische Untersuchung der Assimilations-organe der Podalyrieen nach ökologischen Gesichtspunkt.* Thesis, Kiel, pp. 48; 1913. *See* Just's Jber., Pt. 2, 1124; 1913.

2346. Wall, A. On the distribution of *Senecio saxifragoides* Hook f. and its relation to *Senecio lagopus* Raoul. Trans. N. Zealand Inst. **50,** 198–206; 1918.

2347. Wallis, T. E. True and false Santonicas. Pharm. J. **115,** 148–56; 1925.

2348. —— *Textbook of pharmacognosy.* London, pp. 503; 1946.

2349. Wallis, T. E., and Forsdike, J. L. Palisade ratio. Its value for detecting certain adulterants of Belladonna leaf and Stramonium, especially *Scopolia carniolica* and *Solanum nigrum.* Quart. J. Pharm. **11,** 700–8; 1938.

2350. Wallis, T. E., and Goldberg, S. The histology of *Podophyllum peltatum.* Quart. J. Pharm. **10,** 40–51; 1937.

2351. —— The histology of Indian *Podophyllum.* Quart. J. Pharm. **10,** 311–18; 1937.

2352. Wallis, T. E., and Saunders, A. M. The rhizomes of *Helleborus niger* and *H. viridis*: a comparative study. Pharm. J. **113,** 89–94; 1924.

2353. Walter, H. *Phytolaccaceae* in Engler's *Das Pflanzenreich,* iv. 83; 1909.

2354. —— Über Perldrüsenbildung bei Ampelideen. Flora, Jena, N.S. **14,** 187–231; 1921.

2355. Wangerin, W. *Garryaceae* in Engler's *Das Pflanzenreich,* iv. 56*a*; 1910.

2356. Wangerin, W. *Nyssaceae* in Engler's *Das Pflanzenreich,* iv. 220*a*; 1910.

2357. —— *Alangiaceae* in Engler's *Das Pflanzenreich,* iv. 220*b*; 1910.

2358. —— *Cornaceae* in Engler's *Das Pflanzenreich,* iv. 229; 1910.

2359. Warburg, O. *Sabiaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 5; 1896.

2360. Ward, H. Marshall. On the tubercular swellings on the roots of *Vicia faba.* Philos. Trans. Roy. Soc. B, **178,** 539–62; 1887.

2361. Warington, K. The changes induced in the anatomical structure of *Vicia faba* by the absence of boron from the nutrient solution. Ann. Bot. Lond. **40,** 27–42; 1926.

2362. Warming, E. The structure and biology of Arctic flowering plants. XIII. Caryophyllaceae. Meddel om Gronland, **37,** 229–342; 1920.

2363. Warning, W. C. Anatomy of the vegetative organs of the parsnip. Bot. Gaz. **96,** 44–72; 1934.

2364. Watari, S. Anatomical studies on some leguminous leaves with special reference to the vascular system in petioles and rachises. J. Fac. Sci. Tokyo Univ., Sect. III, **4,** 225–365; 1934.

2365. —— Anatomical studies on the vascular system in the petioles of some species of *Acer,* with notes of the external morphological features. J. Fac. Sci. Tokyo Univ., Sect. III, **5,** 1–73; 1936.

2366. Waterston, E. J. An investigation of leaf and flower structure of *Rhododendron griersonianum* Hook. f. et Forrest., *R. Dalhousiae* Hook. f. and their hybrid *R. Grierdae.* Trans. bot. Soc. Edinb. **33,** 1–11; 1939.

2367. Watkins, K. S. Stem anatomy of chaparral shrubs. Bot. Gaz. **101,** 391–402; 1939.

2368. Watson, E. V. The dynamic approach to plant structure and its relation to modern taxonomic botany. Biol. Rev. Camb. phil. Soc. **18,** 65–77; 1943. *See* Biol. Abstr. **18,** No. 9133; 1944.

2369. Watson, G. H., and James, W. O. Variations in samples of *Digitalis* leaves from British sources. Quart. J. Pharm. **14,** 214–16; 1941.

2370. Watt, G. *The commercial products of India,* pp. 1189; London, 1908.

2371. Webber, I. E. Bearing of upright ray cells in the wood of *Hibiscus mutabilis* L. on the usage of the term tile-cell. Trop. Woods, **37,** 9–13; 1934.

2372. —— The wood of *Hibiscus tiliaceus* L. Trop. Woods, **37,** 14–18; 1934.

2373. —— Systematic anatomy of the woods of the Malvaceae. Trop. Woods, **38,** 15–36; 1934.

2374. —— Systematic anatomy of the woods of the Simarubaceae. Amer. J. Bot. **23,** 577–87; 1936.

2375. —— The woods of sclerophyllous and desert shrubs of California. Amer. J. Bot. **23,** 181–8; 1936.

2376. —— Anatomy of the leaf and stem of *Gossypium.* J. Agric. Res. **57,** 269–86; 1938.

2377. —— Intercellular cavities in the rays of dicotyledonous woods. Lilloa, **2,** 465–69; 1938.

2378. —— Systematic anatomy of the woods of the Burseraceae. Lilloa, **6,** 441–65; 1941.

2379. —— The wood of *Ambelania laxa* Muell. Arg. Lilloa, **11,** 49–53; 1945.

2380. Weber, W. *Beiträge zur vergleichenden Anatomie einiger Familien der Sapindales mit Rücksicht auf die Systematik.* Thesis, Göttingen, pp. 55; 1913. *See* Just's Jber., Pt. 2, 1103; 1913.

2381. Weberbauer, A. *Rhamnaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.* iii. 5; 1896.

2382. Weddell, H. A. Monographie de la famille des Urticées. Arch. Mus. Hist. nat. **9,** 39; 1856–7.

2383. WEEVERS, T. The relation between taxonomy and chemistry of plants. Blumea, **5**, 2. 412–22; 1943.

2384. WEHMER, C. *Die Pflanzenstoffe botanisch-systematisch bearbeitet Phanerogamen.* Jena, 1911 and 1931.

2385. WEIDT, E. Die Entwicklung der Blätter der Melastomaceen *Heterotrichum macrodon* Planch. und *Clidemia hirta* Don. Beitr. Biol. Pfl. **23**, 252–81; 1935.

2386. WEINGART, W. Series of articles on new species of Cactaceae. Mschr. Kakteenk. **24**, 72–8, 81–4, 123–7; 1914. *See* Just's Jber., Pt. 1, 520; 1915.

2387. —— Extranuptiale Nektarien an einem *Phyllocactus.* Mschr. Kakteenk. **30**, 136–8; 1920. *See* Just's Jber., Pt. 2, 95; 1921.

2388. —— *Crassula schmidtii* Regel. Z. Sukkulentenk. **1**, 23–6; 1923.

2389. WEINSTEIN, A. I. Summary of literature relating to volume, distribution and effects of medullary rays in wood. J. For. **24**, 915–25; 1926.

2390. WIESLANDER, A. E., and SCHREIBER, B. O. Notes on the genus *Arctostaphylos.* Madroño, S. Francisco, **5**, 38–47; 1939.

2391. WEISS, F. E. On the leaf tissues of the graft hybrids of *Crataego-mespilus asniersii* and *Crataego-mespilus Dardari.* Mem. Manchester lit. phil. Soc. **69**, 9, pp. 6; 1924/5.

2392. —— Plant structure and environment with special reference to fossil plants. J. Ecol. **13**, 301–13; 1925.

2393. —— Contributions to the anatomy of the foliage leaves of official and pharmaceutically important Compositae. Pharm. J. **115**, 411–12; 1925.

2394. WEITZ, R. Le lyciet (*Lycium vulgare* Dunal); recherches botaniques, chimiques et pharmacologiques. Bull. Sci. Pharm. **28**, 503–8 and 562–8; 1921. *See* Just's Jber., Pt. 1, 682; 1923.

2395. WELCH, M. B. Eucalyptus oil glands. J. roy. Soc. N.S.W. **54**, 208–17; 1920.

2396. —— The resinous exudation of rosewood (*Dysoxylon Fraseranum*). J. roy. Soc. N.S.W. **56**, 233–40; 1922.

2397. —— The secretory epidermal cells of certain eucalypts and angophoras. J. roy. Soc. N.S.W. **57**, 218–26; 1923.

2398. —— Note on the structure of some eucalyptus woods. J. roy. Soc. N.S.W. **58**, 169–76; 1924.

2399. —— The microscopical identification of timber. Aust. For. J. **8**, 8–10; 1925.

2400. —— A further contribution to the knowledge of the silky oaks. J. roy. Soc. N.S.W. **58**, 255–67; 1925.

2401. —— Notes on the principal indigenous timbers of the Natural Order Saxifragaceae. J. roy. Soc. N.S.W. **59**, 276–92; 1925.

2402. —— The identification of the principal ironbarks and allied woods. J. roy. Soc. N.S.W. **59**, 329–45; 1926.

2403. —— The wood structure of certain Eucalypts belonging chiefly to the 'Ash' group. J. roy. Soc. N.S.W. **60**, 147–66; 1927.

2404. —— Notes on some Australian timbers of the Monimiaceae. J. roy. Soc. N.S.W. **62**, 350–65; 1929.

2405. —— Walnut bean (*Endiandra palmerstonii*). Trop. Woods, **20**, 4–9; 1929.

2406. —— Description and properties of red satinay. J. roy. Soc. N.S.W. **63**, 122–30; 1930.

2407. —— The occurrence of intercellular canals in the wood of some species of *Flindersia.* J. roy. Soc. N.S.W. **64**, 352–62; 1931.

2408. —— Queensland 'Maple' (*Flindersia* spp.). Trop. Woods, **25**, 18–23; 1931.

2409. WELCH, M. B., MCGLYNN, W., and COOMBS, F. A. Notes on wattle barks, Pt. I. J. roy. Soc. N.S.W. **57**, 313–33; 1923.

2410. WENT, F. A. F. C. Untersuchungen über Podostemonaceen. Verk. Akad. Wet. Amst. **16**, 1. 1–88; 1910. **17**, 2. 1–19; 1912. **25**, 1. 1–59; 1926.

2411. —— Sur la transformation du collenchyme en sclérenchyme chez les Podostemonacées. Rec. Trav. bot. néerland. **21**, 513–20; 1924.

2412. Wenzel, H. Die Mangroverinden als Gerbmaterialen. Anatomische Untersuchungen der gerbstoffreichsten Mangroverinden. Bot. Arch. **12**, 59–96; 1925.

2413. Werdemann, E. Zur mikroskopischen Erkennung von Opiumpulver. Angew. Bot. **4**, 92–5; 1922.

2414. Werner, O. Haar- und Cystolithenscheiben in Blattgeweben bei Urticales, bei *Bryonia dioica* und *Zexmenia longipetiolata*. Öst. bot. Z. **80**, 81–97; 1931.

2415. Wernham, H. F. The systematic anatomy of the genus *Canephora*. Beih. bot. Zbl. **28**, 1. 453–77; 1912.

2416. Wettstein, R. *Handbuch der systematischen Botanik*. Ed. 4. Leipzig und Wien, Band I, 1933; Band II, 1935.

2417. Whitaker, E. S. The anatomy of certain golden rods. Bot. Gaz. **65**, 250–60; 1918.

2418. —— Root hairs and secondary thickening in the Compositae. Bot. Gaz. **76**, 30–59; 1923.

2419. White, A., Dyer, R. A., and Sloane, B. L. *The succulent Euphorbieae*. Vol. i, S. Africa; 1941.

2420. White, P. R. Studies of the physiological anatomy of the strawberry. J. Agric. Res. **35**, 481–92; 1927.

2421. Wieland, C. R. Wood anatomy and angiosperm origin. Trop. Woods, **39**, 1–11; 1934.

2422. Wierletak, J. The chemical composition of wood of *Trochodendron aralioides*. J. For. **29**, 64–7; 1931.

2423. Wiesner, J. *Die Rohstoffe des Pflanzenreiches*. Leipzig, vols. i and ii, pp. 2253; 1927.

2424. Wilke, Fr. *Beiträge zur Kenntnis der Gattung Mesembryanthemum*. Thesis, Halle, pp. 48; 1913. *See* Just's Jber., Pt. 2, 1104; 1913.

2425. Wille, N. Om Stammens og Bladets Bygning hos *Myriocarpa cordifolia* Liebm. Biologiske Arbeider tilegnede Eug. Warming. 265–79; 1911. *See* Just's Jber., Pt. 2, 1070; 1911.

2426. Williams, Ll. Studies of tropical American woods. Trop. Woods, **15**, 14–24; 1928.

2427. —— The wood of *Caryodendron angustifolium* Standley. Trop. Woods, **20**, 26–7; 1929.

2428. —— Peruvian mahogany. Trop. Woods, **31**, 30–7; 1932.

2429. —— A study of the Caryocaraceae. Trop. Woods, **42**, 1–18; 1935.

2430. —— *Woods of Northeastern Peru*. Field Museum, Chicago, pp. 587; 1936.

2431. —— Note on *Calatola venezuelana* Pittier. Trop. Woods, **56**, 6–9; 1938.

2432. —— *Maderas Económicas de Venezuela*. Min. Agr. & Cria, Carácas, Bol. Técn. No. 2; 1939.

Williams, S. Secondary tissues of the oaks indigenous to the United States:

2433. I. The importance of secondary xylem in delimiting *Erythrobalanus* and *Leucobalanus*. Bull. Torrey bot. Cl. **66**, 353–65; 1939.

2434. II. Types of tyloses and their distribution in *Erythrobalanus* and *Leucobalanus*. Bull. Torrey bot. Cl. **69**, 1–10; 1942.

2435. III. A comparative anatomical study of the wood of *Leucobalanus* and *Erythrobalanus*. Bull. Torrey bot. Cl. **69**, 115–29; 1942.

2436. Willis, J. E. The evolution of the Tristichaceae and Podostemonaceae I. Ann. Bot. Lond. **40**, 349–67; 1926.

2437. Wilson, C. L. Medullary bundle in relation to primary vascular system in Chenopodiaceae and Amaranthaceae. Bot. Gaz. **78**, 175–99; 1924.

2438. —— Adventitious roots and shoots in an introduced weed. Bull. Torrey bot. Cl. **54**, 35–8; 1927.

2439. Wilton, O. C., and Roberts, R. H. Anatomical structure of stems in relation to the production of flowers. Bot. Gaz. **98**, 1. 45–64; 1936.

2440. Winkler, H. *Betulaceae* in Engler's *Das Pflanzenreich*, iv. 61; 1904.

2441. —— *Linaceae* in Engler and Prantl's *Die natürl. Pflanzenfam.*, Auf. 2, 19A; 1931.

2442. Winter, C. W. Vascular system of young plants of *Medicago sativa*. Bot. Gaz. **94**, 1. 152–67; 1932.

2443. Winton, K. B. Comparative histology of alfalfa and clover. Bot. Gaz. **57**, 53–63; 1914.

2444. Winton, A. L., and Winton, K. B. *The structure and composition of foods*. New York, 2 vols.; 1932/5.

2445. Wirth, E. H. A study of *Chenopodium ambrosioides* var. *anthelmintium* and its volatile oil. J. Amer. pharm. Ass. **9**, 127–41; 1920.

2446. —— The pharmacognosy of *Ceanothus americanus*. Amer. J. Pharm. **98**, 503–14; 1926.

2447. —— *Xanthoxylum*. National Formulary Bull. **9**, 149–50; 1941. *See* Biol. Abstr. **16**, No. 23055; 1942.

2448. —— *Viburnum crassuloides*. National Formulary Bull. **9**, 150–1; 1941. *See* Biol. Abstr. **16**, No. 23056; 1942.

2449. Withner, C. L. Stem anatomy and phylogeny of the Rhoipteleaceae. Amer. J. Bot. **28**, 872–8; 1941.

2450. Wolf, F. A. Notes on the anatomy of *Opuntia Lindheimeri* Englm. Plant World, **15**, 294–7; 1912.

2451. Wolf, F. A., and Jones, E. F. Comparative structure of green leaves of oriental tobacco at different levels on the stalk in relation to their quality upon curing. Bull. Torrey bot. Cl. **71**, 5. 512–28; 1944.

2452. Wolff, H. *Umbelliferae-Apioideae-Bupleurum, Trinia et reliquae Ammineae heteroclitae* in Engler's *Das Pflanzenreich*, iv. 228; 1910.

2453. —— *Umbelliferae-Saniculoideae* in Engler's *Das Pflanzenreich*, iv. 228; 1913.

2454. —— *Umbelliferae-Apioideae, Ammineae-Carinae, Ammineae novemjugatae et genuinae* in Engler's *Das Pflanzenreich*, iv. 228; 1927.

2455. Wonisch, F. Die Sekretgänge von *Monophyllaea, Klugia* und *Rhynchoglossum*. Öst. bot. Z. **59**, 209–15; 1909.

2456. Wood, F. H. Observations on the development of a pink colour in lignified tissues by the chloramine reaction. Ann. Bot. Lond. **41**, 281–5; 1927.

2457. Wood, J. G. On transpiration in the field of some plants from the arid portions of S. Australia, with notes on their physiological anatomy. Trans. roy. Soc. S. Aust. **47**, 259–78; 1923.

2458. —— The relations between distribution, structure and transpiration of arid South Australian plants. Trans. roy. Soc. S. Aust. **48**, 226–35; 1924.

2459. —— The physiology of xerophytism in Australian plants. The stomatal frequencies, transpiration and osmotic pressures of sclerophyll and tomentose-succulent-leaved plants. J. Ecol. **22**, 69–87; 1934.

2460. Woodcock, E. F. Anatomy of the leaf of the black raspberry (*Rubus occidentalis* L.). Pap. Mich. Acad. Sci. **11**, 333–40; 1929.

2461. —— Vegetative anatomy of the tomato (*Lycopersicum esculentum* Mill.). I. Stem structure. Pap. Mich. Acad. Sci. **21**, 215–22; 1935.

2462. Woodcock, E. F., and Zeeuw, R. de. The anatomy of the haustorial roots of *Comandra*. Rep. Mich. Acad. Sci. **22**, 189–92; (1920) 1921.

2463. Woodhead, H. Studies in growth and differentiation. V. Histological and metabolic changes during wound-healing in *Kleinia articulata* Haw. Ann. Bot. Lond. **48**, 467–80; 1934.

2464. Woodworth, R. H. Diaxylary laticiferous cells of *Beaumontia grandiflora*. J. Arnold Arbor. **13**, 35–6; 1932.

2465. —— Perforated fiber-tracheids in the passion flowers. Science, **80**, 449–50; 1934.

2466. —— Fibriform vessel members in the Passifloraceae. Trop. Woods, **41**, 8–16; 1935.

2467. WORSDELL, W. C. On the comparative anatomy of certain species of the genus *Christisonia*. Ann. Bot. Lond. **9,** 103–36; 1895.

2468. —— Internal phloem in *Myristica*. Ann. Bot. Lond. **22,** 526–7; 1908.

2469. —— A study of the vascular system in certain orders of the Ranales. Ann. Bot. Lond. **22,** 651–82; 1908.

—— The origin and meaning of medullary (intraxylary) phloem in the stems of dicotyledons:

2470. I. Cucurbitaceae. Ann. Bot. Lond. **29,** 567–90; 1915.

2471. II. Compositae. Ann. Bot. Lond. **33,** 421–58; 1919.

2472. —— The structure of fasciated plants of *Campanula carpetica* Jacq. New Phytol. **28,** 150–61; 1929.

2473. WORSLEY, R. R. LE G. The histology and physiology of Rotenoids in some Papilionaceae. I. Ann. Appl. Biol. **26,** 649–82; 1939.

2474. WRAY, E. M. The structural changes in a woody twig after summer pruning. Proc. Leeds phil. lit. Soc. **2,** 560–70; 1934.

2475. WRIGHT, J. Notes on strand plants. II. *Cakile maritima* Scop. Proc. bot. Soc. Edinb. **29,** 389–401; 1927.

2476. WYK, J. H. VAN. A key to the more important indigenous and exotic timbers grown or marketed in South Africa. Ann. Univ. Stellenbosch, **13A,** 1–29; 1935.

2477. WYLIE, R. B. The role of the epidermis in foliar organization and its relations to the minor venation. Amer. J. Bot. **30,** 273–80; 1943.

2478. YAMABAYASHI, N. Types of vessel perforations in Korean woods. Trop. Woods, **46,** 20–2; 1936.

2479. —— Identification of Korean woods. Bull. For. Exp. Sta. Chosen, No. 27; 1938.

2480. YAMAGUCHI, Y. Über das Auftreten der Verbänderung bei *Pharbitis hederacea* Chois. J. Fac. Sci. Tokyo Univ. **39,** 2, pp. 56; 1916–19.

2481. YAMPOLSKY, C. The cytology of the abscission zone in *Mercurialis annua*. Bull. Torrey bot. Cl. **61,** 279–89; 1934.

2482. YAPP, R. H. *Spiraea Ulmaria* and its bearing on the problem of xeromorphy in marsh plants. Ann. Bot. Lond. **26,** 815–70; 1912.

2483. YARBROUGH, J. A. Anatomical and developmental studies of the foliar embryos of *Bryophyllum calycinum*. Amer. J. Bot. **19,** 443–53; 1932.

2484. —— Histology of leaf development in *Bryophyllum calycinum*. Amer. J. Bot. **21,** 467–82; 1934.

2485. YATSENKO-KHMELEVSKY, A. The crystalliferous parenchyma in the wood of certain Caucasian Rosaceae. Proc. Tbilisi. Bot. Inst. **1,** 282–93; 1933.

2486. —— Variations in structure of wood of oriental beech (*Fagus orientalis* Lipsky), as influenced by age, level and the environment. Bull. Acad. Sci. Armenian S.S.R., No. 5; 1946.

2487. —— The wood structure of some species of the genus *Nothofagus* Bl. in connection with its systematic position. Proc. Acad. Sci. Armenian S.S.R. **2,** 109–13; 1945.

2488. YATSENKO-KHMELEVSKY, A., and DJAPARIDZE, L. I. *Glossary of terms used in describing woods*. Tiflis Botanical Institute, Tiflis; 1936.

2489. YORK, H. H. The anatomy and some of the biological aspects of the 'American mistletoe' *Phoradendron flavescens* (Pursh.) Nutt. Bull. Univ. Texas, No. 120, 1–31; 1909.

2490. YOUNGKEN, H. W. *Ballota hirsuta*, a recent adulterant of *Marrubium vulgare*. Amer. J. Pharm. **91,** 3. 147–56; 1919.

2491. —— The comparative morphology, taxonomy and distribution of the Myricaceae of the Eastern United States. Contr. bot. Lab. Univ. Pa. **4,** 339–400; 1919.

2492. —— *Digitalis sibirica*. J. Amer. pharm. Ass. **8,** 923–8; 1919.

2493. Youngken, H. W. Observations on Muira-Puama. J. Amer. pharm. Ass. **10,** 690–2; 1921.

2494. —— Studies of the bark of *Myrica cerifera* Linn. J. Amer. pharm. Ass. **12,** 484–8; 1923. *See* Just's Jber., Pt. 1, 711; 1923.

2495. —— The anatomy and botanical position of Miré. J. Amer. pharm. Ass. **14,** 195–200; 1925.

2496. —— Black chokeberry bark as a substitute for *Viburnum cassinoides*. J. Amer. pharm. Ass. **18,** 1225–8; 1929.

2497. Youngken, H. W., and Feldmarr, H. F. The pharmacognosy of *Chionanthus*. Sci. Ed. Amer. pharm. Ass. **31,** 5. 129–35; 1942.

2498. Youngken, H. W., and Munch, J. C. *Viburnum alnifolium*. J. Amer. pharm. Ass. **29,** 439; 1940. *See* Quart. J. Pharm. **13,** 358; 1940.

2499. Youngman, W., and Pande, S. S. Occurrence of branched hairs in cotton and upon *Gossypium Stocksii*. Nature, Lond. **119,** 745; 1927.

2500. —— The epidermal outgrowths of the genera *Thespesia* and *Gossypium*. A morphological study throwing some light upon the evolution of the hairs constituting commercial cotton. Ann. Bot. Lond. **43,** 711–40; 1929.

2501. Yuncker, T. G., and Gray, W. D. Anatomy of Hawaiian Peperomias. Bernice P. Bishop Mus. Occasional Papers, **10,** 20, pp. 19; 1934.

2502. Zamels, A., and Paegle, P. Untersuchungen über den anatomischen Bau der Blattstiele in der Gattung *Pulsatilla* Tourn. Acta Hort. bot. Univ. latv. **2,** 133–64; 1927. *See* Bot. Zbl. n.s. **13,** 7; 1928/9.

2503. Zander, A. Über Verlauf und Entstehung der Milchröhren des Hanfes (*Cannabis sativa*). Flora, Jena, **123,** 191–218; 1928.

2504. Zebe, V. *Monographie der Sterculiaceen-gattungen Kleinhovia, Helicteres, Reevesia, Ungeria und Pterospermum*. Thesis, Breslau, pp. 63; 1915. *See* Just's Jber., Pt. 1, 520; 1915.

2505. Zemke, E. Anatomische Untersuchungen an Pflanzen der Nambiwüste (Deutsch-Südwestafrika). Flora, Jena, n.s. **33,** 365–416; 1939.

2506. Ziegenspeck, H. Das anormale Dickenwachstum des Rhizoms von *Hedysarum comosum* als Ursache einer auffälligen Kontraktilität. Bot. Arch. **19,** 344–8; 1927. *See* Bot. Zbl. n.s. **12,** 6; 1928.

2507. Zijlstra, K. Die Gestalt der Markstrahlen im sekundären Holze. Rec. Trav. bot. neérland. **5,** 17–50; 1908.

2508. Zimmerman, A. *Die Cucurbitaceen. Beiträge zur Anatomie, Physiologie, Morphologie, Biologie, Pathologie und Systematik*. Jena, vol. i, pp. 205, vol. ii, pp. 186; 1922.

2509. Zimmerman, P. W. Regulation of plants and formative effects induced with β-naphthoxy compounds. Proc. nat. Acad. Sci. Wash. **27,** 381–8; 1941.

2510. Zornig, H., and Buch, O. Beiträge zur Anatomie des Blattes pharmazeutisch gebräuchlicher Labiaten-Drogen. Arch. Pharm. Berl. **264,** 301–21; 1926. *See* Just's Jber., Pt. 2, 474; 1926.

2511. Zohary, M., and Fahn, A. Anatomical carpobiological observations in some hygrochastic plants of the oriental flora. Palestine J. Bot. **2,** 125–31; 1941.

2512. Zwicky, L. Über Channa ein Genussmittel der Hottentotten (*Mesembryanthemum expansum* L. und *tortuosum* L.). Vjschr. naturf. Ges. Zürich, **58,** 371–430; 1913. Also Thesis, Zürich, pp. 60; 1914. *See* Just's Jber., Pt. 2, 1105; 1913.

SUPPLEMENTARY LITERATURE

2513. Balwant Singh. The anatomy of the stem, leaf and petiole of *Zanonia indica* L. J. Indian bot. Soc. **21,** 319–26; 1942.

2514. Campbell, W. G., Packman, D. F., and Rolfe, D. M. The composition and origin of a white deposit found in galleries of a wood boring insect in two samples of the wood of *Qualea* sp. Emp. For. J. **24,** 232–3; 1945.

2515. Chennery, E. M. Aluminium in trees. Emp. For. Rev. **25,** 255–6; 1946.

2516. Cookson, I. C. On fossil leaves (Oleaceae) and a new type of fossil pollen grain from Australia's brown coal deposits. Proc. Linn. Soc. N.S.W. **72,** 183–97; 1947.

2517. Cozzo, D. Anatomía del leño secundario de *Tricomaria usillo* Gill. ex H. et A. Lilloa, **13,** 17–21; 1947.

2518. Esau, K. Seasonal changes in the phloem of *Vitis vinifera*. Amer. J. Bot. **34,** 583; 1947.

2519. Fanshawe, D. Studies of the trees of British Guiana. Trop. Woods, **90,** 30–40; 1947, **92,** 25–40; 1948, **93,** 1–28; 1948.

2520. George, E. Senna leaflets—their palisade ratio values and ranges. Quart. J. Pharm. **16,** 226–32; 1943.

2521. —— The palisade ratio values of *Atropa belladonna* and *Atropa acuminata.* Quart. J. Pharm. **19,** 144–54; 1946.

2522. Greguss, P. Bestimmung der mitteleuropäischen Laubhölzer und Sträucher auf xylotomischer Grundlage. (With 250 plates, 4 special plates and 2 charts.) Budapest, pp. 183; 1945.

2523. Heintzelman, C. E., Jun., and Howard, R. A. The comparative morphology of the Icacinaceae V. The pubescence and crystals. Amer. J. Bot. **35,** 42–52; 1948.

2524. Jeuch, J. Vergleichende pharmakognostische Untersuchung der Drogen aus den Genera *Arctium* und *Petasites* unter besonderer Berücksichtigung der anatomischen Verhältnisse. Ber. Schweiz. bot. Ges. **51,** 5–76; 1941.

2525. Keen, G. R. West African timbers. Wood, **12,** 172–6; 1947.

2526. Livingston, G. A., and Addicott, F. T. Mechanical factors in foliar abscission of *Citrus*. Amer. J. Bot. **34,** 586; 1947.

2527. Mangenot, G. Recherches sur l'organisation d'une Balanoporacée; *Thonningia coccinea* Vahl. Rev. gén. Bot. **54,** 201–44; 1947.

2528. Melville, C. The histology of belladonna root. Part I. *Atropa belladonna* Linn. II. Indian belladonna. Quart. J. Pharm. **17,** 201–20; 1944. III. Differential characters for the powder. Quart. J. Pharm. **18,** 331–8; 1945.

2529. —— Ipecacuanha—Differential histological characters for the commercial varieties. Quart. J. Pharm. **19,** 292–301; 1946.

2530. Normand, D. Caractéristiques de quelques bois des Comores. Agron. trop. **2,** 399–405; 1947.

2531. Schaeppi, H. Morphologische Untersuchungen einiger Viscoideen. Mitt. naturw. Ges. Winterthur, **24,** 59–86; 1945.

2532. Scott, F. M., Schroeder, M., and Turrell, F. M. Cell shape in the leaf of the Valencia orange and other leaves. Amer. J. Bot. **34,** 588; 1947.

2533. —— Leaf abscission in the Valencia orange and suberization of the internal surface of the Valencia and other leaves. Amer. J. Bot. **34,** 589; 1947.

2534. Rowson, J. W. The significance of stomatal index as a differential character. III. Studies on the genera *Atropa, Datura, Digitalis, Phytolacca* and in polyploid leaves. Quart. J. Pharm. **19,** 136–44; 1946.

2535. Wallis, T. E., and Santra, D. K. Determination of clove stalk in powdered clove. Quart. J. Pharm. **20,** 291–8; 1947.

INDEX

In order to reduce the length of the index, genera have been entered only where they occur in the lists at the ends of the families, where they are mentioned elsewhere than in the families to which they belong, and where they are illustrated. The references to illustrations are distinguished by heavy figures. All taxonomic units above the rank of genera have been indexed wherever they occur. Species names are not included.

Abarema, 487.
Abatia, 680.
Abatieae, 126.
Abauria, 501.
Abaxial parenchyma, *see* Parenchyma.
Abelia, **754,** 758.
Aberemoa, **48,** 49.
Aberia, 127.
Abietinic acid crystals, 1214.
Abobra, 691.
Abramsia, 776.
Abroma, 253.
Abrophyllum, 568.
Abrus, 533.
Abscission tissue, 162, 302, 545.
Absinthium, 802.
Abura, 774.
Abuta, 57, **60.**
Abutilon, **228,** 233.
Acacia, **482,** 487, **536.**
Acacieae, 479.
Acaciella, 487.
Acaena, 549.
Acalypha, 348, **1216,** 1234, 1235.
Acalypheae, 1209, 1212, 1215, 1221, 1223, 1225, 1227.
Acanthaceae, 1014–23.
Acantheae, 1015.
Acanthella, 648.
Acantholimon, **854,** 857.
Acanthomintha, 1052.
Acanthonema, 1002.
Acanthopanax, **728, 732,** 735.
Acanthopsis, 1023.
Acanthosicyos, **688,** 691.
Acanthosphaera, 1270.
Acanthosyris, **1198,** 1201.
Acanthus, **1018,** 1023.
Acaranga, 916.
Acer, **412, 434,** 435, 436.
Aceraceae, 429, 431–6.
Acharia, 681.
Achariaceae, 680–1.
Achatocarpaceae, 1090.
Achatocarpus, **1088,** 1091.
Achillea, **784, 788,** 803.
Achimenes, **998,** 1002.
Achlys, 63.
Achras, 880.
Achyranthes, 1074.
Achyronichia, 152.
Achyropappus, 803.
Acicarpha, 782.
Acicular crystals, 1345.
Acidocroton, 1234, 1235.
Acid, tannic, 292.
Acioa, 553.
Aciotis, 648.
Aciphylla, 724.
Acisanthera, 648.
Ackama, 564.
Acleisanthes, 1067.
Acmadenia, 316.
Acmanthera, 285.
Acmea, 629.
Acnida, 1074.
Acnistus, 970, 977, 978.
Acokanthera, 904, 916, 917.
Aconite root, 6.
Aconitum, **2,** 7.
Acradenia, 316.
Acridocarpus, 285.
Acrocarpus, 501.
Acrodiclidium, 1155.
Acronychia, 316.
Acrosanthes, 711.
Acrotrema, 11.
Acrotriche, 847.
Actaea, 7.
Actephila, 1234.
Actinidia, 10, **186, 192,** 193.
Actinidiaceae, 10, 126, 191–3.
Actinocytic stomata, xv, 221.
Actinodaphne, 1155.
Actinodium, 630.
Actinolepis, 803.
Actinomeris, **788,** 803.
Actinomyces, 1293.
Actinophora, 262.
Actinostemma, 691.
Actinostemon, 1234, 1235.
Adansonia, 241.
Adansonieae, 235, 241.
Adelia, **1226,** 1235.
Adeliopsis, 57.
Adelobotrys, 648.
Adenandra, 316.
Adenanthera, 487.
Adenanthereae, 479.
Adenanthos, 1168.
Adenaria, 654.
Adenia, **672,** 680.
Adenocalymma, **1004,** 1011.
Adenocarpus, 533.
Adenocline, 1234, 1235.
Adenogramma, 711.
Adenopeltis, 1234, 1235.
Adenophora, 816.
Adenoplea, 932.
Adenoplusia, 932.
Adenopus, 691.
Adenosacme, 775.
Adenostemma, 711, 803.
Adenostoma, 549, 833.
Adenostyles, 803.
Adesmia, 533.
Adhatoda, **1012,** 1023.
Adina, **766,** 775, 776.
Adinandra, 126, **186,** 190, 191.
Adinobotrys, **482,** 487.
Adiscanthus, 316.
Adlumia, 79.
Adolia, 413.
Adonis, **2,** 7.
Adoxa, 759.
Adoxaceae, 758–9.
Adriana, 1234.
Adromischus, 581.
Aegialitis, **852,** 857.
Aegiceras, **864, 868,** 871.
Aeginetia, 991.
Aegiphila, 1040, 1041.
Aegle, 316.
Aeglopsis, 316.
Aegopodium, **714,** 724.
Aeolanthus, 1052.
Aeonium, 581.
Aerenchyma, 91, 477, 481, 503, 513, 637, 642, 649, 651, 664, 665, 667, 870.
Aerva, **1064, 1068,** 1074.
Aeschrion, 325, **334.**
Aeschynanthus, **998,** 1002.
Aeschynomene, **526,** 533, 534.
Aesculus, 434, **438,** 441.
Aethusa, 724.
Aextoxicon, 1234.
Afara, 619.
Affonsea, 487.
Afraegle, 316.
African Blackwood, 533.
African Mahogany, 357.
African Tea, 396.
African Walnut, 357.
Afrormosia, **520,** 534.
Afzelia, **494,** 501.
Agalma, 735.
Agapetes, **824,** 827.
Agatea, 108.
Agathosma, 316.
Agauria, 836.
Agdestis, 1091.
Agelaea, 475.

Ageratum, 803.
Aggregate rays, *see* Rays.
Aglaia, 357, 358.
Agonandra, 381, **388.**
Agrimonia, **542,** 549.
Agriophyllum, 1084.
Agrostistachys, 1234, 1235.
Aguiaria, 241.
Ahernia, 127.
Ailanthus, **322,** 325, **334,** 1051.
Ainsliaea, 803.
Aiouea, **1150,** 1155.
Aitonia, 357.
Aizoon, **708,** 711.
Ajuga, 1052.
Akania, 429, **434, 436,** 439.
Akaniaceae, 429, 436–9.
Akebia, **60, 65,** 66.
Akee Apple, 430.
Alangiaceae, 741–5.
Alangium, **742,** 745, **746.**
Albertinia, 803.
Albertisia, 57.
Albizzia, **482,** 487.
Albuminosae, 333, 338.
Alchemilla, **542,** 549, 555.
Alchornea, 1234, 1235.
Alchorneopsis, 1235.
Alcimandra, 21.
Aldehyde in leaf, 681.
Alder, 1305.
Aldrovanda, **582,** 585.
Alectorolophus, 987.
Alectryon, 430.
Aleurites, 1234, 1235.
Alexa, 534.
Alfaroa, 1290.
Alhagi, 533.
Alibertia, 775, 776.
Aliform parenchyma (in wood), xxiv, xlvi, l.
Alismataceae, 5.
Alkanet Root, 954.
Alkanna, 954.
Alkannin, 953.
Allaeanthus, 1270.
Allamanda, 916, 917.
Allanblackia, 178, 179.
Allantoma, 636.
Allenrolfea, 1084.
Allmania, 1074.
Allomorphia, 648.
Allophylus, 430.
Alloplectus, 1002.
Allotropa, 840.
Allspice, 629.
Allspice, Carolina, 16.
Alluaudia, 448.
Almeidea, 316.
Almonds, Bitter, 548.
— Indian, 619.
— Sweet, 548.
Alniphyllum, 890.
Alnus, **1300,** 1305, **1306.**
Aloewood, 1173.
Aloinopsis, 711.
Alona, **962,** 964.
Alonsoa, **982,** 987, 988.
Alphitonia, 411, 413.
Alphonsea, **48,** 49.
Alphonseopsis, 49.
Alseia, 775, 776.
Alseodaphne, 1155.
Alseuosmia, 758.
Alsike Clover, 532.
Alsodeia, 108, 1230.
Alsodeiopsis, **372,** 376.
Alsomitra, **688,** 691.
Alstonia, **904, 910,** 916, 917.
Alternanthera, 1074.
Alternate intervascular pitting, xliii.
Althaea, **224,** 233, **244.**
Althoffia, 262.
Altingia, **590,** 592.
Alumina bodies, 891.
Aluminium (in wood), l.
Alvaradoa, 325.
Alvaradoideae, 320, 324, 325.
Alyogyne, 233.
Alysicarpus, 533.
Alyssum, **80, 84,** 87.
Alyxia, 917.
Amaioua, 775, 776.
Amanoa, 1234.
Amanoinae, 1220.
Amaralia, 775.
Amaranthaceae, 152, 1067–74, 1082, 1083.
Amaranthus, **1062, 1068,** 1074.
Amaroria, 325.
Amasonia, 1040.
Ambatch, 533.
Ambelania, 917.
Amblygonocarpus, 487.
Amborella, 1144.
Ambrosia, 803.
Ambylanthopsis, 871.
Ambylanthus, 871.
Amelanchier, 549.
Amellus, 803.
Amentiflorae, 748.
American Basswood, 261.
American Hollies, 385.
American Milkweed, 924.
American Pillar Rose, 543, 547.
American Red Gum, 592.
American White Ash, 899.
American Wormseed, 1084.
Amerimnon, 534.
Amherstia, 501, 534.
Amicia, 533.
Ammannia, 654.
Ammi, 724.
Ammobium, 803.
Ammobroma, 851.
Ammodendron, 533, 534.
Ammoniacum, 723.
Ammonium phosphate, excretion of by *Lathraea*, 990.
Ammonium sulphate, excretion of by *Lathraea*, 990.
Amomis, 630.
Amoora, **354,** 357, 358.
Amoreuxia, 115, 126.
Amorpha, 533, 534.
Amorphospermum, 879.
Ampalis, 1270.
Ampelidaceae, 413–19.
Ampelocera, 1278.
Ampelopsis, 419.
Ampelozizyphus, 413.
Amperea, 1234.
Amphiblemma, 648.
Amphicarpaea, 533.
Amphicome, **1004,** 1011.
Amphilophium, 1011.
Amphimas, 501.
Amphirrhox, **106,** 108.
Amphithalea, 533.
Amphorocalyx, 648.
Amsonia, 916.
Amygdalaceae, 548.
Amyris, **312,** 316.
Amyxa, 1179.
Anabasis, 1084.
Anacampseros, 156, 705.
Anacampta, 917.
Anacardiaceae, 137, 314, 347, 348, 357, 429, 451, 452–62, 463, 465, 466, 467, 468, 1289, 1290.
Anacardium, 461.
Anacolosa, 366.
Anacyclus, 152, 803.
Anaectocalyx, 648.
Anagallis, **860,** 862.
Anagyris, 533, 534.
Anamirta, 57.
Anaphalis, 803.
Anaphrenium, 461.
Anarthrophyllum, 533.
Anartia, 917.
Anastatica, 87.
Anastrabe, 988, **1000.**
Anaueria, 1155.
Anaxagorea, **48,** 49.
Anchietea, 108.
Anchovy Pear, 636.
Anchusa, 954.
Anchuseae, 949.
Ancistrocladaceae, 221.
Ancistrocladus, **208,** 219, **221.**
Ancistrothyrsus, 127.
Andaman Marblewood, 886.
Andersonia, 847.
Andinium, 104.
Andira, **522,** 533, 534.
Andiroba, 357.
Andrachne, **1216,** 1234.
Andrographis, 1023.
Andromeda, **824,** 836.
Androsace, **842,** 862.
Androsiphonia, **676,** 680.
Androstachys, 1234.
Andryala, 803.
Anemone, **2,** 7.

Anemonella, 7.
Anemonopsis, 7.
Anemopaegma, 1011.
Anerincleistus, 648.
Anethum, 724.
Aneulophus, 277.
Angelesia, 553.
Angelica, 723.
Angelica, 724.
Angelim, 533.
Angelim Bark, 531.
Angiosperms, 5, 51, 67, 295, 988, 1067.
Angiosperms, origin of, xxx, xli, lii, 1067.
Angophora, **626,** 630.
Angusturo Bark, 315.
Aniba, 1155.
Anisacanthus, **1020,** 1023.
Aniseed, 724.
Aniseia, 964.
Anise, Star, 25.
Anisochilus, 1052.
Anisocytic stomata, xv.
Anisomallon, 376.
Anisomeles, 1052.
Anisomeris, 776, 1091.
Anisophyllea, **606,** 611.
Anisoptera, **208, 214, 218,** 220.
Anisosperma, 691.
Anisotes, 1023.
Anisotome, 724.
Annatto dye, 113.
Anneslea, **186,** 190, 191.
Annona, 49.
Annonaceae, 17, 19, 44–50, 51, 1137, 1143.
Annonales, 38.
Anoda, 233.
Anodendron, 917.
Anodopetalum, 564.
Anogeissus, 620.
Anomalous structure, **xxi,** [1343.
Anomocarpus, 1229.
Anomocytic stomata, xv.
Anomopanax, 735.
Anomospermum, 57, **402.**
Anonocarpus, 1270.
Anopterus, 568.
Anopyxis, **608,** 611.
Anplectrum, 648.
Anredera, 1086.
Antarctic Beech, 1315.
Ant domatia, 641, 677, 760, 771, 947.
Antennaria, 803.
Anthacanthus, 1023.
Anthemis, 803.
Anthenaea, **970,** 978.
Antherotoma, 648.
Anthobolus, 1201.
Anthobryum, 147.
Anthocephalus, 775, 776.
Anthocercis, 977, 978.
Anthochlamys, 1084.
Anthocleista, **930,** 932.
Anthodiscus, 199, **202.**
Anthospermum, 775.
Anthostema, 1235.
Anthotium, 809.
Anthotroche, 977.
Anthriscus, 724.
Anthyllis, 533.
Antiaris, 1229, **1248,** 1270.
Anticharis, 987.
Antidaphne, 1194.
Antidesma, 348, **1220,** 1234.
Antidesminae, 1219, 1221, 1229.
Antigonon, 1100.
Antirrhinum, **982,** 987, 988.
Antirrhoea, 775, 776.
Antizoma, 57.
Antonia, 932.
Antonieae, 931.
Antrocaryon, 461.
Aotus, 533.
Apama, **1088,** 1119.
Aparisthmium, 1235.
Apeiba, 262.
Apeibeae, 261.
Apetahia, 821.
Aphaerema, 127.
Aphananthe, 1278.
Aphania, 430.
Aphanieae, 421.
Aphanococcus, 430.
Aphanomixis, 358.
Aphelandra, 1023.
Aphelandreae, 1015.
Aphloia, 127.
Apinagia, 1104.
Apiopetalum, 735.
Apios, **512,** 533.
Apitong, 220.
Apium, **714, 716,** 724.
Aplopappus, 803.
Apocynaceae, 117, 332, 905–17, 917, 918, 923, 973, 1227, 1230.
Apocynaceae - Echitoideae, 913.
Apocynum, 916.
Apodytes, **372,** 376, **382,** 1230.
Apophyllum, 94.
Apoplanesia, 533, 534.
Aporosa, **1218,** 1229, 1230, 1234.
Aporosa type (of wood), 1208, 1219, 1229, 1230.
Aporosella, 1234.
Aporrhiza, 430.
Appendicularia, 648.
Apple, 548.
Apple, Akee, 430.
— Belle, 680.
— Custard, 49.
— Kei, 127.
Apple rootstocks, 547.
Apple, rubbery wood of, 549.
Apricot, 548.
Aptandra, **360,** 366.
Aptosimum, 987, 988.
Apuleia, 501.
Aquifoliaceae, 381–6, **774,** 834, 871, 1230.
Aquilaria, **1172,** 1178, 1181.
Aquilegia, **2,** 7.
Arabian Tea, 396.
Arabic, Gum, 486.
Arabis, 87.
Arachis, 533.
Aralia, **726, 728,** 735.
Araliaceae, 129, 131, **722,** 723, 725–35, 740.
Aralidium, **732.**
Araliopsis, 316.
Aramina fibre, 233.
Araujia, 924.
Arboreal Lobelias, 819.
Arbuteae, 829.
Arbutus, **824, 826,** 836.
Arcangelisia, 57.
Arceuthobium, **1192,** 1194.
Archangelica, **714,** 724.
Archeria, **842,** 847.
Archichlamydeae, 108.
Archytaea, 190.
Arctium, **788, 790,** 803.
Arctostaphylos, **824,** 836.
Arctotideae, 783.
Arctotis, 803.
Ardisia, **864, 866, 868,** 871.
Ardisiandra, 862.
Arechavaletaia, 127.
Arenaria, 152.
Areoles, 698, 699, 702.
Aretia, 862.
Arfeuillea, 430.
Argania, **878,** 879, 880.
Argemone, 78.
Argithamnia, 1234.
Argophyllum, 568.
Argostemma, 775.
Argyreia, 964.
Argyrodendron, 253.
Argyroderma, 711.
Argyrolobium, 533.
Ariocarpus, 705.
Aristolochia, **1010, 1110, 1116,** 1119.
Aristolochiaceae, 66, 413, 694, 1114–20.
Aristolochiales, 1119.
Aristotelia, **244,** 266.
Arjona, 1201.
Armeria, **854,** 857.
Armoracia, **84.**
Arm-palisade cells, 1, 34, 104, 188, 191, 209, 449, 480, 725, 727, 753, 758, 805, 810, 811, 814, 859, 919, 947, 967, 973, 1129, 1260.
Arnebia, 954.
Arnica, 802.
Arnica, 803.
Aromadendron, 21.
Arrabidaea, 1011.

Arrowroot, substitute for, 963.
Artabotrys, 49.
Artemisia, **784, 790, 792,** 803.
Arthraerua, 1074.
Arthrocnemum, 1084.
Arthrophyllum, 735.
Arthrosolen, 1178, **1182.**
Arthrostema, 648.
Artichoke, Chinese, 1051.
— Globe, 799.
— Jerusalem, 799.
Artocarpeae, 1260, 1261, 1263, 1264.
Artocarpoideae, 1269.
Artocarpus, **1266,** 1270.
Arytera, 430.
Asafoetida, 723.
Asarum, **1110,** 1119.
Ascarina, **1130,** 1132.
Asclepiadaceae, 914, 917–25.
Asclepias, **910, 920,** 924.
Ascyrum, 169.
Ash, American White, 899.
— Australian, 630.
— European, 899.
— Manna, 899.
Ash wood, 630, 899, 1269.
Asimina, 49, **54.**
Aspalathus, 533.
Aspen, 1319.
Asperugo, 954.
Asperula, 775.
Aspicarpa, 285.
Aspidocarya, 57.
Aspidopterys, 285.
Aspidosperma, 916–17.
Astephanus, 924.
Aster, **790,** 803.
Asteranthe, 49.
Asteranthos, 636.
Astereae, 783.
Asteriastigma, 127.
Asterolasia, 316.
Asteropeia, **118,** 127.
Astianthus, 1011.
Astilbe, 557.
Astragalus, **512,** 533, 1112.
Astrantia, 724.
Astrocarpus, 97.
Astronia, 648.
Astronidium, 648.
Astronium, **456,** 461.
Astronoideae, 637, 639, 645, 647.
Astrophytum, 705.
Astrotricha, 735.
Asyneuma, **812,** 816.
Asystasia, **1016, 1018,** 1023.
Atalantia, 316.
Atalaya, 430.
Atamisquea, **88, 92,** 94.
Ateleia, 534.
Athanasia, 803.
Atherosperma, **1140,** 1144.
Atherospermoideae, 1139, 1142, 1143.
Athyana, 430.
Atractylis, 803.
Atraphaxis, **1096,** 1100.
Atriplex, **1072, 1076, 1078, 1080,** 1084.
Atripliceae, 1081.
Atropa, 977, 1091.
Atroxima, 138.
Atylosia, 533.
Aubrietia, **84,** 87.
Aubrya, 279.
Aucoumea, **346,** 349.
Aucuba, **738,** 741, **742.**
Audouinia, 595.
Auerodendron, 413.
Augea, 292.
Aulacocalyx, **766,** 775, 776.
Aulax, 1168.
Australian Blackwood, 486.
Australian Bottle Tree, 249.
Australian Kumquat, 307, 308.
Australian Sandalwood, 1201.
Australian Sassafras, 1144.
Australian Turpentine, 630.
Austrobaileya, 25, **32.**
Austroplenckia, 397.
Auxemma, 954.
Averrhoa, **290,** 303, **334.**
Averrhoidium, 430.
Avicennia, 1007, **1028, 1036,** 1040, 1041.
Avocado Pear, 1153.
Axinaea, 648.
Axinandra, 648.
Axyris, **1076,** 1084.
Ayahuasco, 284.
Aydendron, 1155.
Ayous, 253.
Azadirachta, 358.
Azalea, 836.
Azaleas, 835.
Azara, **118,** 127.
Azima, 903, **904.**
Azorella, 724.

Baccaurea, **1218,** 1234.
Baccharis, **790, 792,** 803.
Backhousia, 630.
Bacteria in roots, 499, 527, 1187.
Bacterial cavities in leaves, 765, 863, 864.
Bacterial nodules, 291.
Badiera, 138.
Badusa, 776.
Baeckia, 630.
Baeria, 803.
Bagassa, 1270.
Bahia, 774.
Baikiaea, **494,** 501.
Baillonia, **1034,** 1040.
Balanites, **290,** 292.
Balanocarpus, **216,** 220.
Balanophora, 1207.
Balanophoraceae, 1200, 1205–1207.
Balanophorin, 1206.
Balanops, 1243.
Balanopsidaceae, 1243, 1289.
Balanostreblus, 1270.
Balata, 879.
Balau, 220.
Balbisia, 297.
Ballota, **1044,** 1052.
Balmea, 776.
Baloghia, 1235.
Balsaminaceae, 297–8.
Balsamocitrus, 316.
'*Balsamodendrum*', 349.
Balsam of Peru, 529.
— of Tolu, 529.
Balsamorhiza, 803.
Balsa wood, 241.
Baltimora, 803.
Banara, 127.
Banded parenchyma (in wood), xxiv.
Bania, 57.
Banisteria, 285.
Banksia, **1164,** 1168.
Baobab, 241.
Baphia, **522,** 533, 534.
Baptisia, 531, 533.
Barbeuia, 1091.
Barbeyastrum, 648.
Barbiera, 533.
Barclaya, 71.
Bargemontia, 964.
Barilla, 1084.
Barleria, **1016, 1018,** 1023.
Barlerieae, 1015.
Barleriola, 1023.
Barnadesia, 803.
Barnhartia, **130,** 138.
Barosma, **306,** 316, **334.**
Barringtonia, **634,** 636.
Barringtonieae, 632.
Barteria, 680.
Bartonia, 939.
Bartsia, 987.
Basanacantha, 775, 776.
Basella, 1086.
Basellaceae, 152, 1084–6.
Bassia, 879, 880, **1078,** 1084.
Bassovia, 977.
Basswood, American, 261.
Bastard Australian Sandalwood, 1027.
Bastardiopsis, 233.
Bast, Cuba, 233.
Bast in rays, 141.
Batesia, 501.
Bathysa, 775, 776.
Batidaceae, 1091–2.
Batidales, 466.
Batis, 1092.
Bauera, 557.
Bauerella, 316.
Bauhinia, **490, 498,** 501, **536.**
Bauhinieae, 495.
Bayberry bark, 1294.
Bay, Sweet, 1153.
Bean, Black, 533.

Bean, Coffee, 532.
— Lima, 532.
— Locust, 500.
— St. Ignatius, 932.
Beatsonia, 147.
Beaufortia, 630.
Beaumontia, 917.
Beauprea, 1168.
Beccarianthus, 648.
Beech, Antarctic, 1315.
— Southland, 1315.
Beech wood, 1315.
Beefwood, 879.
Befaria, 836.
Begonia, **682, 692**, 695.
Begoniaceae, 691–5, 697, 996, 997.
Behaimia, 534.
Behuria, 648.
Beilschmiedia, **1148, 1150**, 1155.
Belairia, 534.
Belangera, 564.
Belladonna, 974.
Belladonna, adulterant in, 325.
Belle Apple, 680.
Bellendena, 1168.
Belliolum, 29.
Bellis, 803.
Bellonia, 1002.
Bellucia, 648.
Belmontia, 939.
Beloperone, **1020**, 1023.
Belotia, 262.
Bembicia, 127.
Benevidesia, 648.
Benincasa, 691.
Bennettia, 127.
Bennettitales, 29, 67.
Benthamantha, 534.
Benzoin, 889.
Benzoin, **1148**.
Berberidaceae, 4, 6, 57, 58–63, 66–74, 463.
Berberidales, 63.
Berberidoideae, 59.
Berberidopsis, **118**, 127.
Berberin, xviii, 1346.
Berberis, **60**, 63, **65**.
Berchemia, 411, 413.
Bergenia, **556**, 557.
Bergeranthus, 711.
Bergeronia, 534.
Bergia, 165.
Bergsmia, 127.
Berkheya, 803.
Berlinia, 501.
Bernardia, 1234.
Bernardinia, 475.
Berneuxia, 850.
Bernoullia, **238**, 241.
Berrya, 262.
Bersama, **434**, 443.
Bertholletia, 636, **638**.
Bertiera, 775, 776.
Bertolonia, 648.
Bertya, 1234.
Berzelia, 595.
Besleria, 1002.
Beta, **1080**, 1084.
Betula, **1300, 1302**, 1305, **1306**.
Betulaceae, 1289, 1302–5, 1309, 1314.
Beyeria, 1234.
Bicollateral Bundles, xxi.
Bidens, 803.
Biebersteinia, 297.
Bigelowia, 803.
Bignonia, **1004, 1010**, 1011.
Bignoniaceae, 1002–13.
Bikkia, 775, 776.
Bilimbi, 303.
Bilinga, 774.
Billardiera, 131.
Billia, 441.
Billian, 1155.
Biophytum, 303.
Biovularia, 994.
Bipinnatae, 479.
Birch 1011, 1305.
Birch wood, 1305.
Bird's-eye Maple, 435.
Birthwort, Indian, 1119.
Bischoffia, 348, 1234.
Bischoffiinae, 1221.
Bisglaziovia, 648.
Bishopwood, 1234.
Bitter Almonds, 548.
Bixa, **106**, 113, 114, **118**, 126.
Bixaceae, 112–13, 114, 115, 119, 125, 126.
Bixales, 126.
Blachia, 1235.
Black Bean, 533.
Blackberry, 548.
Black Cherry wood, 549.
Black Currants, 573.
Black Dammar, 348.
Black Gum, 751.
Black Haw, 757.
Black Hellebore, 6.
Black Manwood, 366.
Black Mulberry, 1269.
Black Oak, 1314, 1315.
Black Sassafras, 1144.
Black Snakeroot, 6.
Blackstonia, 939.
Blackwood, African, 533.
Blackwood, Australian, 486.
Blakea, 648.
Blanchetia, 803.
Blastania, 691.
Blastemanthus, **330**, 338.
Blastus, 648.
Blechum, 1023.
Bleekrodea, 1270.
Blepharandra, 285.
Blepharis, 1023.
Blepharistemma, 611.
Blepharocarya, 461.
Blighia, **426**, 430.
Blumenbachia, **658**, 669.
Bobea, **768**, 775, 776.
Bocagea, 49.
Bocconia, 78, **92**.
Bocote, 953.
Boehmeria, **1248, 1250**, 1253.
Boehmerieae, 1247, 1249.
Boekenhout, 871.
Boenninghausenia, 316.
Boerhaavia, **1060**, 1067.
Boerlagea, 648.
Boerlagiodendron, 735.
Bois de Rose, 1155.
Boldea, 1144.
Boldo leaves, 1144.
Bolivian Coca, 275.
Bombacaceae, 232, 235–42, 252, 253, 254, 257, 260.
Bombacineae, 241.
Bombacopsis, 241.
Bombax, **238**, 241.
Bombycidendron, 233.
Bonafousia, 917.
Bonamia, **956**.
Bonnaya, 987.
Bonnetia, **186**, 189, **192**, 195.
Bonnetiaceae, 193–5.
Bonnierella, 735.
Bonplandia, 942.
Bontia, 1027.
Bonyunia, **930**, 932.
Boopis, 782.
Boraginaceae, 914, 945–54, 963.
Boragineae, 947.
Borago, 954.
Borbonia, 533.
Boronia, 316.
Borreria, 775.
Boschia, 241.
Boscia, **92**, 94.
Bosea, **1064, 1072**, 1074.
Bosistoa, 316.
Bosquiea, 1270.
Bossé, 357.
Bossiaea, 533.
Boswellia, **342, 346**, 349.
Bothriocline, 803.
Bothriospora, 775, 776.
Botryceras, 461.
Bottle Tree, Australian, 249.
Bouchea, 1040.
Bouea, 461.
Bougainvillaea, **1058, 1062**, 1067.
Bourreria, 954.
Bousigonia, 917.
Boussingaultia, **1080**, 1086.
Bouvardia, 775.
Bowdichia, 533, 534.
Bowlesia, **712**, 724.
Boxes, 630.
Boxwood, 774, 916, 1241.
Boxwood substitutes, 314, 396.
Boxwood, West Indian, 127.
Boykinia, 557.
Brabejum, 1168.

Brachistus, **970**, 978.
Brachychiton, **246**, 253.
Brachycome, 803.
Brachylaena, **792**, 803.
Brachyloma, 847.
Brachynema, 886.
Brachyotum, 648.
Brachysema, 533.
Brachysiphon, 1183.
Brachystegia, 501.
Brackenridgea, **330**, 338.
Bracteanthus, 16, 1144, 1153, 1159.
Brasenia, **68**, 71.
Brasilettia, 501.
Brassaia, 735.
Brassaiopsis, 735.
Brassiantha, 403.
Brassica, **84**, 87, **92**.
Bravaisia, **1020**, 1023.
Brazilian Rosewood, 533.
Brazil Nut, 636.
Brazilwood, 500.
Brazoria, 1052.
Brazzeia, 268.
'Breathing' roots, *see* pneumatophores.
Bredemeyera, 138.
Bredia, **638**, 648.
Bretschneidera, 441.
Breweria, 964.
Brexia, **556**, 568.
Breynia, 1234.
Brickellia, 803.
Bridelia, 348, **1220**, 1234.
Bridelieae, 1209, 1222.
Bridgesia, 430.
Brieya, 49.
Brittenia, 648.
Brochoneura, 1138.
Brongniartia, 533.
Broom, Spanish, 529.
Brosimeae, 1269.
Brosimopsis, 1270.
Brosimum, **1248**, **1264**, 1270.
Broussaisia, 577.
Broussonetia, **1262**, **1266**, 1270.
Broussonetieae, 1269.
Browallia, 977.
Brownea, 501, **536**.
Brown Ebony, 533.
Browneopsis, 501.
Brownlowia, 262.
Brownlowieae, 254, 255, 257, 258, 261.
Brucea, **322**, 325.
Brucine, 932.
Brugmansia, 977, 978, 1113.
Bruguiera, **598**, **606**, 611.
Bruinsmea, 890.
Brunellia, 324, 328, **334**.
Brunelliaceae, 326–8, 361, 564, 568.
Brunfelsia, **968**, 977.
Brunia, 595.
Bruniaceae, 594–5.
Brunnichia, 1100.
Brunonia, 809.
Brunoniaceae, 807.
Brush Box, 630.
Brya, 533, 534.
Bryocarpum, 862.
Bryonia, **688**, 691.
Bryonopsis, 691.
Bryony, White, 691.
Bryophyllum, **570**, 581.
Bryophyta, 1101.
Bubbia, 29.
Bubinga, 500.
Buchanania, 461.
Buchenavia, 620.
Buchenroedera, 533.
Bucholzia, 94.
Buchu leaves, 314, 315.
Bucida, 620.
Buckeye, Ohio, 441.
Bucklandia, 592.
Bucklandioideae, 589.
Buckleya, 1201.
Buckwheat, 1100.
Bucquetia, 648.
Budda, 1027.
Buddleia, **920**, **926**, **930**, 932.
Buddleioideae, 925, 926, 928, 931.
Buettnerieae, 232, 252.
Buettnerioideae, 242, 243, 245, 247, 249, 252, 253, 254.
Buffonia, 152.
Bulletwood, 879.
Bulnesia, **290**, 292.
Bumelia, **874**, **878**, 879, 880.
Bunchosia, 285, **290**.
Bundles, bicollateral, xxi.
Bundles, cortical, xxi, 1342.
Bundles, medullary, xxi, 1342.
Bundles, vascular, diagnostic value, xx.
Bunias, **84**, 87.
Bupleurum, **716**, 724.
Burasaia, 57.
Burchellia, 775, 776.
Burdachia, 285.
Burkea, 501.
Burma Mahogany, 261.
Burma Yellowheart, 932.
Bursaria, **120**, 131.
Bursera, 349.
Burseraceae, 314, 341–9, 356, 357, 429, 459, 1230, 1289.
Burtonia, 533.
Burttia, 475.
'Bush Tea' of Queensland, 1051.
Bussea, 501.
Butea, **520**, 533, 534.
'Butter Nuts', 199.
Buttonia, 987, 990.
Buttress roots, 235, 240, 251.
Butyrospermum, 880.
Buxaceae, 1229, 1236–41, 1281.
Buxus, **1238**, **1240**, 1241.
Byblidaceae, 585–6.
Byblis, 586.
Byronia, 385.
Byrsanthus, 127.
Byrsocarpus, 475, 476.
Byrsonima, 285, **290**.
Bystropogon, 1052.

Caapi, 284.
Cabbages, 86.
Cabomba, 71.
Cabralea, 357, 358.
Cacabus, 977.
Cacalia, 803.
Caccinia, **950**, 954.
Cachrys, 724.
Cacoucia, 620.
Cactaceae, 156, 698–706, 711, 913.
Cactus, **700**, 705.
Cadaba, **88**, **92**, 94.
Cadellia, 325.
Caesalpinia, 501.
Caesalpiniaceae, 476, 485, 487–501, 503, 519, 521, 524, 527, 528, 529, 538.
Caiophora, 669, **670**.
Cajanus, 533.
Cajuput Oil, 629.
Cakile, 87.
Calabashes, 1011.
Calamander, 886.
Calamiformes, 479.
Calancoba, 1230.
Calandrinia, **154**, 156.
Calandriniopsis, 156.
Calantica, 127.
Calatola, 376.
Calceolaria, **982**, 987, 988.
Calcium carbonate, 1317.
Calcium carbonate (in wood), 237, 259, 427, 433, 440, 645, 875, 1037, 1275, 1313.
Calcium malate crystals, 709, 894, 1214.
Calcium oxalate (in wood), l.
Calcium phosphate crystals, 709, 919, 1085, 1214.
Calcium phosphate (in wood), 1037.
Caldcluvia, 564.
Calderonia, 776.
Calendula, 803.
Calliandra, 487.
Callicarpa, **1034**, **1036**, 1040, 1041.
Callichlamys, 1011.
Callicoma, 564.
Calligonum, 1100.
Callipeltis, 775.
Callistemon, **624**, 630.
Callistephus, 803.
Callisthene, 142.
Callitrichaceae, 599.
Callitriche, 599.
Calluna, 836.

Callus formation, 227.
Calocarpum, **878.**
Calocephalus, 803.
Calodendrum, **312,** 316.
Calogyne, 809.
Caloncoba, 127.
Calonyction, 964.
Calophaca, 533.
Calophylloideae, 169, 171, 175, 178, 272.
Calophyllum, **166, 170, 172, 176,** 178, 179, 181.
Calopogonium, 533.
Calothamnus, **624,** 630.
Calotropis, 924.
Calpidia, 1067.
Calpocalyx, 487.
Calpurnia, 533.
Calumba Root, 57.
Calvaria, 880.
Calvoa, 648.
Calycanthaceae, 13–16, 568, 1143.
Calycanthus, **12, 14,** 16.
Calycarpum, 57.
Calyceraceae, 781–2.
Calycodendron, 776.
Calycogonium, 648.
Calycolpus, 630.
Calycophyllum, 775, 776.
Calycopteris, **598, 614,** 620.
Calycorectes, 630.
Calycosia, 776.
Calycotome, 533, 534.
Calyptranthes, **626,** 630.
Calyptrella, 648.
Calyptridium, 156.
Calystegia, **958,** 964.
Calythrix, 630.
Camarea, **280,** 285.
Cambessedesia, 648.
Cambia, successive, 1343.
Cambial initials, length of, xliv.
Cambiform fibres (in wood), 1174.
Cambiform rows of cells, 1053.
Cambiform tissue, bundles of, 1056, 1228.
Cambium, fascicular, xxxiii.
Cambium, interfascicular, xxxiii.
Cambium, interfascicular, absent, 3, 299.
Camellia, **186,** 190, 191, **192.**
Camelliae, 190.
Camellias, 190.
Cameraria, 917.
Campano, 190.
Campanula, **812,** 816.
Campanulaceae, 810–16, 820, 821, 1021.
Campanulatae, 806.
Campanumoea, 816.
Campderia, 1100.
Camphor, 220, 1154.
Camphorosma, 1084.
Camphor Wood, 1155.
Campnosperma, **456,** 461.
Campomanesia, **626,** 630.
Campsiandra, 501.
Campsis, 1011.
Camptosema, 533.
Camptostemon, **238,** 241.
Camptostylus, 127.
Camptotheca, **750,** 752.
Campylostachys, 1040, 1041.
Campylostemon, 403.
Canals, intercellular (in wood), li, 1353.
Canals, latex, 1349.
Canals, laticiferous (in wood), 683.
Canals, mucilage, 1349.
Canals, resin, 1349.
Canals, secretory, 1348.
Cananga, 49, **54.**
Canariellum, 349.
Canarina, 816.
Canarium, **342, 346,** 349.
Canary Whitewood, 19.
Canavalia, **508,** 533, 534.
Canella, 111, **118.**
Canellaceae, 109–11, 1137, 1157.
Canephora, 775.
Cannabinaceae, 272, 1246, 1254–7, 1269, 1277.
Cannabis, 33, 1246, **1254,** 1257, **1274.**
Cannaboideae, 1268, 1269.
Canotia, **330,** 332, **334.**
Canscora, 939.
Cansjera, **368,** 381.
Canthium, 775, 776.
Cantleya, **372,** 376.
Cantua, 942.
Cape Gooseberry, 974.
Caperonia, 1234.
Capers, 94.
Cape Sumac, 1201.
Cape Teak, 932.
Capirona, 776.
Cappareae, 89.
Capparidaceae, 87–95, 97, 305, 324, 470.
Capparis, **88, 90,** 94, **96.**
Capraria, 987.
Caprifoliaceae, 752–8, 975.
Capsella, **80.**
Capsicodendron, 111.
Capsicum, **968, 970,** 977, 978.
Capsicums, 974.
Caragana, **512,** 533.
Caraipa, 178, 179, **182, 208.**
Caraipi tree, 553.
Carallia, 611.
Caralluma, 924.
Carambola, 303.
Carapa, 357, 358.
Caraway seeds, 723.
Cardamine, 87.
Cardiandra, 577.
Cardiochlamys, **956,** 964.
Cardionema, 152.
Cardiopteris, 376.
Cardiospermum, 430.
Cardón, 705.
Cardopatium, 803.
Carduus, 803.
Cardwellia, **1166,** 1168.
Careya, 636.
Carica, **682,** 683.
Caricaceae, 681–3.
Cariniana, **634,** 636.
Carionia, 648.
Carissa, 917.
Carlemannia, **750.**
Carlina, **784,** 803.
Carmichaelia, 533.
Carnations, 152.
Carnegiea, **696,** 705.
Carob, 500.
Carolina Allspice, 16.
Carolinea, 241.
Caromandel wood, 886.
Carpacoce, 775.
Carpenteria, 577.
Carpinus, 1289, **1300, 1302,** 1305, **1306,** 1309.
Carpodetus, 568.
Carpodinus, 917.
Carpodiptera, 262.
Carpolobia, **130, 136,** 138.
Carpotroche, 127.
Carreto, 916.
Carrierea, 127.
Carronia, 57.
Carrot, 723.
Carruanthus, 711.
Carruthersia, 917.
Carthamnus, 803, 976.
Carum, **714,** 724.
Carya, **1280, 1286,** 1290.
Caryocar, 199, **202,** 340.
Caryocaraceae, 195–9, 340.
Caryodendron, 1235.
Caryophyllaceae, 147, 147–53, 156, 164, 721, 802, 1073.
Caryophyllaceae-Polycarpeae, 149.
Caryophyllaceous stomata, xiv.
Caryophylleae, 149.
Caryopteris, **1034,** 1040, 1041.
Caryospermum, 397.
Casasia, 776.
Cascara Sagrada, 411.
Cascarilla, 775.
Cascarilla Bark, 1233.
Cascaronia, 534.
Casearia, **120,** 127.
Cashalia, 534.
Cashew Nuts, 460.
Casimiróa, 316.
Casparian thickenings in endodermis, 6, 196, 198, 304, 418, 642, 651, 759, 761,

765, 766, 788, 797, 813, 814, 857, 939, 942, 972, 981, 1019, 1033, 1048, 1055, 1056, 1073, 1123, 1183, 1187, 1258, 1325.
Cassandra, 836.
Cassava, 1232.
Casselia, 1040.
Cassia, **490**, **494**, 501.
Cassine, 397.
Cassinia, 803.
Cassinopsis, 376.
Cassiope, **828**, 836.
Cassipourea, **608**, 611.
Cassytha, 1155.
Castalia, 71.
Castanea, **1306**, **1312**, 1315.
Castaneae, 1310.
Castanola, 475.
Castanopsis, **1302**, **1312**, 1315.
Castanospermum, 533, 534.
Castanospora, 430.
Castela, 325.
Castelineae, 320.
Castelnavia, 1104.
Castilla, 1270.
Castilleja, 987, 988.
Castilloa, 1270.
Castor Oil, 1232.
Castratella, 648.
Casuarina, **1296**, **1300**, 1301.
Casuarinaceae, 1290, 1294–1301, 1305.
Catalpa, **1006**, **1008**, 1011.
Catananche, **784**.
Catesbaea, 775, 776.
Catha, **382**, 397.
Cathcartia, 78.
Cathedra, 366.
Cathormion, 487.
Catocoryne, 648.
Catostemma, **240**, 241.
Catostemmataceae, 241.
Caucalis, 724.
Caucanthus, 285.
Cauliflowers, 86.
Caulophyllum, 63.
Caulotretus, 501.
Cavanillesia, **240**, 241.
Cavendishia, 827.
Cavities, mucilage, 1348.
Cavities, secretory, 1348.
Cavities, tanniniferous, 1348.
Caylusea, 97.
Ceanothus, **408**, 411, 413.
Ceara Rubber, 1232.
Cecropia, **1264**, 1270.
Cedar, 357.
— Spanish, 357.
— White, 1011.
Cedrela, **350**, **354**, 357, 358.
Cedreleae, 351.
Cedrelinga, 487.
Cedronella, 1052.
Ceiba, 241.
Celaenodendron, 1235.
Celastraceae, 126, 131, 207, 272, 387–97, 398, 399, 403,
Celastrales, 375. [404, 1230.
Celastrus, **392**, 397.
Celery, 723.
Cells, cristarque, 1343.
Cells, laticiferous, 1347.
Cells, mucilage, 1347, 1354.
Cells, myrosin, 1347.
Cells, oil, 1347, 1354.
Cells, resin, 1347.
Cells, secretory, 1347.
Cells, tannin, 1348.
Celmisia, 803.
Celosia, **1062**, 1074.
Celsia, 987.
Celtis, **1274**, **1276**, 1278.
Cenia, 803.
Cenolophium, 724.
Cenostigma, 501.
Centaurea, 803.
Centaurium, **934**, 939.
Centauropsis, 803.
Centradenia, **638**, **640**, 648.
Centranthus, 779.
Centrolobium, **504**, 533, 534.
Centronia, **646**, 648.
Centroplacus, 127.
Centropogon, **818**, 821.
Centrosema, 533.
Centrospermae, 152, 156, 705, 711, 1067, 1073, 1083, 1085.
Centunculus, 862.
Cephaelis, 108, **764**, 775, 776.
Cephalandra, 691.
Cephalanthus, 775, 776.
Cephalaralia, 735.
Cephalaria, **778**, 781.
Cephalocereus, 705.
Cephalocroton, 1234.
Cephalohibiscus, **228**, 233.
Cephaloideae, 1269.
Cephalophora, 803.
Cephalosphaera, **1134**, 1138.
Cephalostigma, 816.
Cephalotaceae, 73, 557–60.
Cephalotus, 73, **558**, 560.
Ceranthera, 1052.
Ceraria, 156.
Cerastium, 152.
Ceratiola, 1324.
Ceratiosicyos, 681.
Ceratocarpus, 1084.
Ceratonia, 501.
Ceratopetalum, **562**, 564.
Ceratophyllaceae, 1325.
Ceratophyllum, **1324**, 1325.
Ceratostema, 827.
Ceratostigma, 857.
Ceratotheca, 1014.
Cerbera, 917.
Cerberiopsis, 917.
Cercidiphyllaceae, 30–1, 42.
Cercidiphyllum, **14**, 31, **32**.
Cercidium, 501.
Cercis, 501.
Cerdia, 152.
Cereus, **700**, 705.
Cerinthe, 954.
Ceriops, 611, 612.
Cerocarpus, 549.
Ceropegia, 924.
Cervantesia, **1198**, 1201.
Cespedesia, 338.
Cestrum, 977, 978.
Chadsia, 533.
Chaenomeles, 549.
Chaerophyllum, **716**, 724.
Chaetachme, **1276**, 1278.
Chaetanthera, 803.
Chaetocalyx, 533, 1023.
Chaetocarpinae, 1231.
Chaetocarpus, **1224**, 1234, 1235.
Chaetolepis, 648.
Chaetoptelea, 1278.
Chaetostoma, 648.
Chailletia, **360**, 361.
Chalogeton, 1084.
Chamaebatia, 549.
Chamaelaucium, 630.
Chamaenerion, 667.
Chamaepericlymenum, 741.
Chamaeranthemum, 1023.
Chamaesaracha, 977.
Chamaesenna, 501.
Chamissoa, 1074.
Chamomile, 802.
Champak, 19.
Champereia, **380**, 381, **388**.
Chapmannia, 533.
Chaptalia, 803.
Characters, plasticity of, xii.
Charcoal, 411.
Chardinia, 803.
Charianthus, 648.
Charieis, 803.
Charpentiera, 1074.
Chasalia, 775, 776.
Chasmanthera, 57.
Chasmatophyllum, 711.
Chaulmoogra Oil, 127.
Chaunochiton, 366.
Chavica, 1127.
Cheiloclinium, 403.
Cheiranthera, 131.
Cheiranthodendron, 253.
Cheiranthus, **80**, **84**, 87.
Cheiridopsis, 711.
Cheirodendron, 735.
Cheirolaena, 253.
Cheirostemon, 253.
Chelidonium, **76**, 78.
Chelone, 987.
Chelonopsis, 1052.
Chengal, 220.
Chenolea, **1078**, 1084.
Chenopodiaceae, 671, 976, 1071, 1073, 1074–84, 1085, 1091.
Chenopodium, 976, **1076**, **1080**, 1084.
Cherry Birch, 1305.
Cherry Mahogany, 879.

Cherry wood, 549.
Chestnut, 1315.
Chestnut, Horse, 441.
Chestnuts, 1315.
Chestnuts, Water, 667.
Chewing-gum, 879.
Chicory, 799.
Childlowia, 501.
Chilianthus, 932.
Chillies, 974.
Chilocarpus, 917.
Chilopsis, 1011.
Chimaera, periclinal, 518.
Chimaphila, 836.
Chimarrhis, 775, 776.
Chimonanthus, **12**, 16.
Chinese Artichoke, 1051.
Chinese Hemp, 233.
Chiococca, 775.
Chionanthus, **888**, **898**, 900.
Chione, 775, 776.
Chirata, 939.
Chirita, 1002.
Chironia, 939.
Chiropetalum, 1234.
Chisocheton, 357, 358.
Chitonia, 292.
Chlaenaceae, 222–3.
Chlaenandra, 57.
Chlamydocarya, 376.
Chloantheae, 1033, 1035.
Chloanthes, 1040, 1041.
Chloranthaceae, 63, 1126, 1127, 1128–32.
Chloranthus, **1124**, 1126, 1132.
Chlorocodon, **920**, 924.
Chloroleucon, 487.
Chlorophora, **1264**, 1270.
Chloroxylon, **312**, 357.
Choisya, 316, **334**.
Chomelia, 775, 776.
Chondrilla, 803.
Chondrodendron, 57.
Chondrostylis, 1234.
Chonemorpha, 917.
Choretrum, 1201.
Chorilaena, 316.
Chorisia, 241.
Chorizanthe, 1100.
Chorizema, 533.
Christiana, **256**, 262.
Christisonia, 991.
Christmas Rose, 6.
Chrysanthemum, **784**, 803.
Chrysil, 802.
Chrysobalanoideae, 539, 548, 550–3.
Chrysobalanus, 553.
Chrysochlamys, 178, 179.
Chrysophyllum, **874**, **878**, 879, 880.
Chrysosplenium, 557.
Chrysothamnus, 803.
Chukrasia, **354**, 357, 358.
Chuquiraga, 803.
Chydenanthus, 636.
Chymococca, 1178.
Chytranthus, 430.
Chytroma, 636.
Cicendia, 939.
Cicer, 533.
Cichoreae, 783, 786.
Cichorium, 803.
Cicuta, 724.
Cienfuegosia, 233.
Cimicifuga, 6.
Cimicifuga, 7.
Cinchona, **764**, 775, 776, 893.
Cineraria, 803.
Cinnamodendron, 111.
Cinnamomum, **1150**, 1155.
Cinnamon, 1154.
Cinnamosma, **106**, 111.
Cipadessa, 358.
Circaea, 667.
Circaeaster, 63, 1131.
Circaeasteraceae, 63, 1131.
Cirsium, **784**, **788**, 803.
Cissampelos, 57.
Cissus, **416**, 419.
Cistaceae, 97–102, 126.
Cistanthera, **256**, 262.
Cisteae, 99.
Cistus, **98**, **100**, 102, **106**, 1051, 1112.
Citharexylum, 1040, 1041.
Citric acid, 709.
Citriobatus, 131.
Citronella, 376, 385.
Citropsis, **312**, 316.
Citrullus, 691.
Citrus, 316, **334**.
Citrus fruits, 314.
Cladostemon, 94.
Cladostigma, 964.
Cladothrix, **1068**.
Cladrastis, **522**, 533, 534.
Claoxylon, **1226**, 1234, 1235.
Clarisia, 1270.
Clarkia, 667.
Clathrotropis, 533, 534.
Clausena, 316.
Clausenopsis, 316.
Clavija, **864**, **866**, **868**, 871.
Cleghornia, 917.
Cleidion, **1226**, 1234, 1235.
Cleistanthus, **1220**, 1234, 1235.
Cleistocalyx, 629.
Cleistopholis, 49.
Clematis, **2**, 7, 14, 66, 850.
Clematis, cuttings of, 4.
Clematoclethra, 10, 190.
Cleobulia, 533.
Cleome, 94, **96**.
Cleomeae, 89.
Clermontia, 821.
Clerodendron, **1028**, **1034**, 1040, 1041.
Clethra, **838**, 839, **848**.
Clethraceae, 835, 836–9.
Cleyera, **182**, 190, 191, **192**.
Clianthus, 533.
Clidemia, 648.
Cliffortia, 549.
Cliftonia, 387, **388**.
Climate, and phylogeny, xxxiii.
Clitandra, 917.
Clitoria, 533.
Clover, alsike, 532.
— red, 532.
Cloves, 629.
Clusia, **172**, **174**, 178, 179, 181.
Clusieae, 169, 171, 178.
Clusioideae, 169.
Cluster crystals, 1344.
Cluytia, 1234.
Cluytiandra, 1234–5.
Cluytieae, 1223, 1225, 1227.
Clytostoma, 1011.
Cneoraceae, 324, 328–31, 347.
Cneoridium, 316.
Cneorum, 329, **330**.
Cnesmone, 1234, 1235.
Cnestidium, 475, 476.
Cnestis, 475, 476.
Cnicothamnus, 803.
Cnicus, 803.
Cnidoscolus, 1234.
Coachwood, 564.
Cobaea, **940**, 942.
Coca, Bolivian, 275.
— Huanuco, 275.
— Peruvian, 275.
— Truxillo, 275.
Cocaine, 275.
Coccinia, 691.
Coccoceras, 1234, 1235.
Coccocypselum, 775.
Coccoloba, **1088**, **1096**, 1100.
Coccoloboideae, 1093, 1097.
Cocculus, 57.
Cochineal, 705.
Cochlearia, 87.
Cochlianthus, 533.
Cochlospermaceae, 113, 114–15, 119, 126.
Cochlospermum, **106**, 115, 126.
Cocillana Bark, 357.
Cocoa, 253.
Coco Plum, 553.
Cocus wood, 533.
Codia, 564.
Codiaeum, 1234, 1235.
Codiocarpus, 376.
Codon, 945.
Codonacanthus, 1023.
Codonocarpus, 1091.
Codonopsis, **812**, 816.
Coelanthium, 711.
Coelidium, 533.
Coelocarpum, 1040.
Coelocaryon, **1134**, 1138.
Coelodepas, 1235.
Coelodiscus, 1234.
Coelostegia, **238**, 241.

Coffea, **764**, 775, 776.
Coffee, 772, 799.
Coffee Bean, 532.
Coffee Tree, Kentucky, 500.
Cogwood, Jamaican, 411.
Coinochlamys, 932.
Cojoba, 487.
Cola, **246**, 253.
Colea, 1011.
Coleanthera, 847.
Coleonema, 316.
Coleostachys, 285.
Coleus, **1044**, 1052, 1053.
Colignonia, 1067.
Colleters, 596.
Colletia, **408**, 411, 413.
Colletieae, 406.
Colliguaja, 1234, 1235.
Collinsia, 988.
Collinsonia, 1052.
Collomia, 942.
Colmeiroa, 557.
Colobanthus, 152.
Cologania, 533.
Colombian Mahogany, 636.
Colombo Root, 57.
Colquhounia, 1052.
Colubrina, **408**, 411, 413.
Columbia, **256**, 262.
Columellia, 995.
Columelliaceae, 995.
Columnea, **998**, 1002.
Colutea, 533.
Colza Oil, 86.
Comandra, 1201.
Comanthosphace, **1044**, 1052.
Combretaceae, 15, 101, 612–20, 620, 621, 751.
Combretocarpus, 612.
Combretodendron, **634**, 636.
Combretum, **614**, **616**, 620.
Cometes, 152.
Commercial cork, 1315.
Commersonia, 253.
Commiphora, 349.
Comocladia, 461.
Comolia, 648. [976.
Compositae, 781, 782–804,
Compound ray, xxxiv.
Compound scalariform perforation plates, 1135.
Compound xylem, 1343.
Compsoneura, **1134**, 1138.
Comptonia, **1280**.
Conceveiba, 1234, 1235.
Conceveibastrum, 1235.
Conchopetalum, 430.
Condalia, 411, 413.
Condaminea, 775.
Condurango Bark, 924.
Condylocarpus, **402**, 917.
Confluent parenchyma (in wood), xxiv, xlvi, l.
Congea, 1040, 1041.
Coniferae, 29, 693.
Conium, **714**, 724.
Connaraceae, 471–6.
Connaropsis, **290**, 303.
Connarus, **472**, 476.
Conocarpus, **614**, 620.
Conocephaleae, 1260, 1261, 1263, 1264.
Conocephaloideae, 1229, 1268, 1269.
Conocephalus, 1270.
Conomorpha, 871.
Conopharyngia, 917.
Conopholis, 991.
Conophyllum, 711.
Conophytum, 711.
Conostegia, 648.
Conostephium, 847.
Contractile exodermis, 5, 1038.
Contractile roots, 300, 302, 704, 720.
Conuleum, 1144.
Convolvulaceae, 954–64, 1067, 1145.
Convolvulus, **952**, **958**, **962**, 964.
Conzattia, 501.
Copaiba, 500.
Copaifera, 501.
Copalchi Bark, 315, 1233.
Copper in ash, 319.
Coprosma, 775, 776.
Coptis, 7.
Coptosapelta, 775.
Corallocarpus, 691.
Corchorus, **244**, 262.
Cordaitales, 29.
Cordemoya, 1234.
Cordia, **946**, **950**, **952**, 954.
Cordyla, 501, 533.
Corema, 1324.
Coreopsis, 803.
Coriandrum, **716**, 724.
Coriaria, **450**, 468.
Coriariaceae, 347, 461, 466–8.
Coriariales, 468.
Coris, 862.
Corispermum, **1076**, 1084.
Cork, xix.
Cork, commercial, 1315.
Cork, crystals in, 908, 1217.
Cork, exogenous, in roots, 797.
Cork, in stem, deep-seated, 1339.
Cork, in stem, superficial, 1339.
Cork, interxylary, 667, 795, 798.
Cork, lignified, 1040.
Cork, medullary, 310, 810, 813, 1057.
Cork, sclereids in, 730, 959, 1133.
Cork, stone cells in, 139, 615, 808, 928, 969, 1273.
Cork warts, 171, 183, 196, 200, 307, 381, 383, 391, 400, 462, 551, 565, 587, 602, 621, 639, 660, 726, 906, 926, 1121.
Cormonema, 411, 413.
Cornaceae, 722, 734, 735–41, 741, 745, 748.
Cornel, 741.
Cornulaca, 1084.
Cornus, **738**, 741, **742**, **750**.
Cornutia, **1036**, 1041.
Corokia, 741, **750**.
Coronilla, 533.
Corpuscularia, 711.
Correa, 316.
Corrigiola, 152, 802.
Cortex, fibres in, 134, 204, 288, 391, 403, 513, 541, 597, 721, 896, 919, 1019, 1217.
Cortex, sclereids in, 27, 140, 189, 288, 856, 861, 1237.
Cortex, sclerosed or sclerotic cells in, 75, 204, 222, 386, 454, 462, 465, 566, 588, 595, 721, 748, 766, 788, 882, 999, 1025, 1047, 1081, 1089, 1141, 1243, 1265.
Cortex, spirally thickened cells in, 83.
Cortex, stone cells in, 23, 46, 55, 57, 86, 134, 161, 162, 173, 180, 215, 224, 227, 236, 245, 278, 282, 286, 288, 309, 320, 327, 336, 339, 344, 350, 351, 359, 369, 377, 384, 391, 400, 423, 433, 439, 447, 452, 454, 481, 492, 503, 513, 541, 594, 604, 623, 642, 697, 730, 737, 749, 831, 867, 882, 885, 891, 896, 908, 919, 928, 931, 936, 969, 1005, 1019, 1095, 1117, 1138, 1141, 1147, 1163, 1183, 1191, 1195, 1197, 1203, 1208, 1217, 1243, 1249, 1265, 1292, 1317, 1321.
Cortex, tracheids in, 158.
Cortical bundles, xxi, 1342.
Cortusa, 862.
Corydalis, 79.
Corylaceae, 1305, 1305–9.
Corylopsis, **584**, 592.
Corylus, 1289, **1300**, **1302**, 1305, **1306**, 1309.
Corynanthe, 775, 776.
Corynella, 533.
Corynocarpaceae, 462–3, 468.
Corynocarpus, **450**, 463, **470**.
Corynostylis, 108.
Coryphantha, 705.
Coscinium, 57.
Cosmelia, 847.
Cosmibuena, 776.
Cosmocalyx, 776.

Cosmos, **790**, 803.
Cossignia, 430.
Cotema, 1011.
Cotinus, **450**, 461.
Coto Bark, 1155.
Cotoneaster, **542**, **544**, 549.
Cotton, 232.
Cotton, Silk, 241.
Cottonwoods, 1319.
Cotylanthera, 939.
Cotyledon, 581.
Cotylelobium, 220.
Cotylodiscus, 430.
Couepia, 553.
Coula, 366.
Coula Nut, 366.
Couleae, 362, 375, 378.
Couma, 917, 973.
Coumarin, xviii.
Coumarouna, 534.
Couralia, 1011.
Couratari, 636.
Courbonia, 94.
Couroupita, 636.
Coursetia, 534.
Cousinia, 803.
Coussapoa, 1229, 1270.
Coussarea, 775, 776.
Coutarea, **766**, 775, 776.
Couthovia, 932.
Cowberry, 825.
Crabbea, 1023.
Crabwood, 357.
Craibiodendron, 836.
Crambe, **84**, 87.
'Cramp Bark', 757.
Cranberry, 825.
Craniolaria, 1014.
Craniotome, 1052.
Cranocarpus, **504**, 533.
Craspidospermum, 917.
Crassula, **558**, **570**, 581.
Crassulaceae, 295, 578–81.
Crataegomespilus, 549.
Crataegus, 549.
Crataeva, **92**, 94, 95, **96**.
Craterispermum, **766**, 775, 776.
Craterogyne, 1270.
Craterostigma, 988.
Cratoxyleae, 167.
Cratoxylon, 169, **176**.
Cratylia, 533.
Crawfurdia, 939.
Cremastus, 1011.
Crenea, 654.
Creochiton, 648.
Creosote Plant, 291.
Crepidospermum, **342**, 349.
Crepis, 803.
Crescentia, 1011.
Cressa, 964.
Cricket-bat Willow, 1320.
Crinodendron, **264**, 266.
Cristaria, 233.
Cristarque cells, 1343, 1346.
Crithmum, **714**, **716**, 724.
Crocanthemum, 102.
Crossandra, **1018**, 1023.
Crossonephelis, 430.
Crossopteryx, 775, 776.
Crossosoma, **12**, 13.
Crossosomataceae, 11–13.
Crossostemma, **676**, 680.
Crossostylis, 611.
Crotalaria, 533, 534.
Croton, 315, **1210**, **1216**, **1226**, 1234, 1235.
Crotoneae, 1209, 1212, 1214, 1215, 1223, 1225.
Crotonogyne, 1234.
Crotonoideae, 1208, 1221, 1223, 1227, 1228, 1230, 1231, 1235.
Croton Oil, 1233.
Crotonopsis, 1234.
Crowea, 316.
Crucianella, 775.
Cruciferae, 79–87, 94, 97, 305, 470, 664, 665.
Cruciferous stomata, xiv.
Cruckshankia, 775.
Crudia, 501.
Crumenaria, 411.
Crusea, 775.
Cryophytum, **708**.
Cryptadenia, 1178.
Cryptandra, 411.
Crypteronia, **652**, 656.
Crypteroniaceae, 655–6.
Cryptocarpus, 1067.
Cryptocarya, 1144, **1150**, 1155.
Cryptolepis, 924.
Cryptostegia, 924.
Cryptostemma, 803.
Crystalline masses, 1346.
Crystalline protein bodies, 981.
Crystalloids, nuclear, 1005.
Crystals, acicular, 1345.
Crystal-sand, 1346.
Crystal-sand (in wood), 771.
Crystals, cluster, 1344.
Crystals, diagnostic value of, xviii.
Crystals, geniculate, 55, 197, 198.
Crystals in cork, 908, 1217.
Crystals in epidermis, 11, 37, 44, 45–6, 54, 59, 91, 110, 117, 273, 287, 288, 289, 309, 490, 502, 510, 511, 844, 865, 907, 966, 993, 1019, 1025, 1035, 1060–1, 1076, 1122, 1129, 1203, 1263.
Crystals in fibres, 64, 65, 514, 767, 875, 921, 1183, 1292, 1297, 1304, 1317.
Crystals in hairs, 926.
Crystals in idioblasts, 117, 125, 126, 193, 215, 294, 390, 391, 400, 431, 432, 537, 612, 651, 659, 780, 907, 927, 945, 958, 1202, 1208, 1214, 1242, 1258, 1263, 1307.
Crystals in stone cells, 37, 57, 91, 116, 121, 124, 767, 1025, 1035, 1147, 1185, 1191, 1237, 1273, 1281, 1308, 1311.
Crystals of abietinic acid, 1214.
Crystals of calcium malate, 709, 894, 1214.
Crystals of calcium phosphate, 709, 919, 1085, 1214.
Crystals, solitary, 1343.
Crystals, types of, 1343.
Crystals, V-shaped, 927.
Ctenolophon, 273, **276**, 279.
Cuba Bast, 233.
Cubebs, 1127.
Cube Root, 530.
Cubilia, **426**, 430.
Cucumbers, 691.
Cucumis, 691.
Cucurbita, **688**, 691.
Cucurbitaceae, 669, 684–91, 694, 695.
Cudrania, 1229, **1248**, 1270.
Cuervea, 403.
Cullenia, **238**, 241.
Culver's Root, 987.
Cumingea, 241.
Cuminia, 1052.
Cuminum, 724.
Cunila, 1052.
Cunonia, **562**, 564, **570**.
Cunoniaceae, 324, 327, 361, 548, 553, 555, 560–5, 568, 571.
Cunoniales, 443, 557, 568.
Cunuria, **1224**, 1235.
Cupania, 430.
Cupanieae, 421.
Cupaniopsis, 430.
Cuphea, **650**, 654.
Cupheanthus, 630.
Cuphocarpus, 735.
Cupuliferae, 465, 1289.
Curatella, 11.
Currants, 419.
— Black, 573.
— Red, 573.
Curtisia, **738**, 741.
Cuscuta, 964, 1145, 1152.
Cuscuteae, 961.
Cusparia, 316.
Cusparia Bark, 314, 315.
Cuspidaria, 1011.
Cussonia, **732**, 735.
Custard Apple, 49.
Cuttings of *Clematis*, 4.
Cuviera, 776.
Cyamopsis, 533.
Cyananthus, **812**, 816.
Cyanea, 821.

Cyanostegia, 1040.
Cyathocalyx, 49.
Cyathodes, 847.
Cyathopsis, 847.
Cyathula, 1074.
Cybianthus, 871.
Cycadaceae, 67, 820.
Cyclamen, **842, 860,** 862.
Cyclanthera, **688,** 691.
Cyclantheropsis, 691.
Cyclea, 57.
Cycloloma, 1084.
Cyclopia, 533.
Cydista, **1008,** 1011.
Cydonia, 549.
Cylicodiscus, 487.
Cylindropsis, 917.
Cylista, 533.
Cymaria, 1052.
Cymbalaria, 988.
Cymbopetalum, 49.
Cymbosema, 533.
Cynanchum, 924.
Cynara, 803.
Cynocrambaceae, *see* Thelygonaceae.
Cynocrambe, 1259.
Cynoglosseae, 948.
Cynoglossum, **950,** 954.
Cynometra, **494,** 501.
Cynomorium, 1207.
Cynoxylon, 741, **742, 750.**
Cyphomandra, 977, 978.
Cypselea, 711.
Cyrilla, 387, **388.**
Cyrillaceae, 207, 386–7.
Cyrtandra, 1002.
Cyrtocarpa, 461.
Cystacanthus, 1023.
Cystoliths, 1343, 1346.
Cystoliths (in wood), xviii, 380.
Cysts from idioblasts (in wood), 868, 869.
Cytinus, 1113.
Cytisopsis, 533.
Cytisus, **512,** 533, 534, 706.
Cytology, taxonomic value of, xi.

Daboecia, 836.
Dacryodes, 349.
Dactylocladus, **646,** 648.
Dactylopetalum, 611.
Daedalacanthus, **1018,** 1023.
Daemia, 924.
Dahlia, **788, 790,** 803.
Dais, 1178, **1186.**
Dalbergia, **522,** 533, 534.
Dalbergieae, 505.
Dalea, 533, 534.
Dalechampia, 1234.
Dalechampieae, 1209, 1212.
Dalenia, 648.
Dalhousiea, 533.
Dallachya, 411.
Damiana, 673.
Dammar, 220.
Dammar, Black, 348.
Dammaropsis, 1270.
Damnacanthus, 775, 776.
Dampiera, 809.
Danais, 775.
Dandelion roots, 799.
Daniella, 501.
Danta, 261.
Dapania, 303.
Daphnandra, **1140,** 1144.
Daphne, 1178, **1186.**
Daphnidium, 1155.
Daphniphyllaceae, 1241–3.
Daphniphyllum, **1238, 1240,** 1243.
Daphnopsis, **1172,** 1178.
Darlingia, 1168.
Darlingtonia, 74.
Darwinia, 630.
Dasycoleum, 357.
Dasylepis, 127.
Date Plum, 886.
Datisca, 698.
Datiscaceae, 695–8.
Datura, **968, 970,** 977, 978, 1084.
Daucus, **716,** 724.
Davidia, **742,** 752.
Davidioideae, 740.
Daviesia, 533, 534.
Davilla, 11.
Debregeasia, **1248,** 1253.
Decaisnea, **65,** 66.
Decanema, 924.
Decaschistia, 233.
Decaspermum, **626,** 630.
Deccan Hemp, 233.
Declieuxia, 775.
Decodon, 654.
Decumaria, 577.
Deeringia, 1074.
Degame, 775.
Degeneriaceae, 42.
Dehaasia, 1155.
Deherainia, **866,** 871.
Deianira, 939.
Deidamia, 680.
Deinanthe, 557.
Deinbollia, 430.
Delarbrea, 735.
Delissea, 821.
Delonix, 501.
Delosperma, 711.
Delphinium, 7.
Delpydora, 879.
Demarara Greenheart, 636.
Dendritic pattern of vessels, xlix, 1351.
Dendrobangia, 376.
Dendrobenthamia, 741.
Dendrocereus, 705.
Dendromecon, 78, **92.**
Dendropanax, 735.
Dendrophthora, 1194.
Dendrostylis, 127.
Denhamia, 397.
Dennettia, 49.
Dentella, 775.
Deplanchea, 1011.
Deppea, 775.
Dermatitis, 452, 858.
Dermatobotrys, 988.
Dermatocalyx, **1000.**
Derris, **512,** 533, 534.
Desbordesia, 325.
Desfontainea, **920,** 932.
Desmanthus, 487.
Desmodium, 533, 534.
Desmonema, 57.
Desmoscelis, 648.
Desmostachys, **372,** 376.
Desplatzia, 262.
Detandra, 57.
Detarium, 501.
Deutzia, **556, 558, 576,** 577.
Developmental anatomy, 87, 532, 545, 547, 580, 642, 651, 718, 720, 723, 747, 754, 772, 791, 896, 908, 942, 969, 973, 974, 1005, 1021, 1045, 1219, 1285.
Development of sclerenchymatous idioblasts, 184.
Dhaman, 261.
Diacidia, 285.
Diacytic stomata, xv.
Dialium, **494,** 501.
Dialyanthera, **1132, 1134,** 1138.
Dialycarpa, 241.
Dialypetalanthus, 776.
Dianthera, **1018,** 1023.
Dianthus, 152.
Diapensia, 850.
Diapensiaceae, 849–50.
Diaphragms in pith, 1342.
Diarthron, 1178.
Diascia, 988.
Diatenopteryx, 430.
Dicella, 285.
Dicellandra, 648.
Dicellostyles, 233.
Dicentra, **76,** 79.
Dichaetanthera, 648.
Dichapetalaceae, 16, 358–61.
Dichapetalum, **360,** 361.
Dicheranthus, 152.
Dichilus, 533.
Dichondra, **956,** 964.
Dichopsis, 879, 880.
Dichotomanthes, 549.
Dichroa, **556,** 577.
Dichrostachys, **482,** 487.
Diclidanthera, 137, 139.
Diclidantheraceae, 137, 138–9.
Diclinanona, 49.
Dicliptera, 1023.
Dicliptereae, 1017.
Dicoelia, 1235.
Dicoma, 803.
Dicorynia, 501.
Dicoryphe, 592.

Dicotyledons, 5, 28, 68, 820, 988, 1188, 1194.
Dicraea, 1104.
Dicranolepis, 1178, **1182.**
Dicranostyles, 964.
Dicraspidia, **264,** 266.
Dicraurus, **1068,** 1074.
Dictamnus, **306,** 316.
Dictyandra, 776.
Dictyoloma, 316, 325.
Dictyoneura, 430.
Dicymbe, 501.
Dicypellium, 1155.
Didelotia, 501.
Didierea, 448.
Didiereaceae, 447–8.
Didymopanax, 735.
Didymotheca, 1091.
Diervilla, **756,** 758.
Diffuse-in-aggregates (parenchyma in wood), xxiv.
Digitalis, 975, 988.
Dika Nut, West African, 325.
Dilkea, 680.
Dillenia, 11, **12, 20.**
Dilleniaceae, 7–12, 13, 15, 19, 38, 126, 190, 193, 210, 419, 1168.
Dilleniales, 10, 190.
Dill-water, 723.
Dillwynia, 533.
Dimorphandra, 501.
Dimorphocalyx, 1235.
Dimorphotheca, 803.
Dinemagonum, 285.
Dinizia, 501.
Dinophora, 648.
Dioclea, 533.
Diodia, 775.
Diolena, 648.
Dionaea, **582,** 585.
Dioncophyllum, 127.
Dionychia, 648.
Dionysia, 862.
Diosma, 316.
Diosmin, 306, 309, 310.
Diospyros, **878, 882, 884,** 886.
Dipanax, 735.
Dipelta, **754, 756,** 758.
Dipentodon, 127, 395.
Diphaca, 533.
Dipholis, 880.
Diphylleia, 63.
Diphysa, 533, 534.
Diplacus, 988, **1000.**
Dipladenia, 917.
Diplanthera, 1011.
Diplarpea, 648.
Diploclisia, 57.
Diplodiscus, 262.
Diploglottis, 430.
Diplokeleba, 430.
Diplolaena, 316.
Diplopeltis, 430.
Diplopterys, 285.
Diplorrhynchus, **910,** 917.
Diplospora, 775, 776.
Diplotaxis, 87.
Diplotropis, 533, 534.
Diplusodon, 654.
Diplycosia, 836.
Dipsacaceae, 779, 780–1.
Dipsacus, **778,** 781.
Dipterocarpaceae, 178, 212–20, 221, 223, 337, 338, 1283.
Dipterocarpus, **214, 216,** 220.
Dipteronia, 435, 436.
Dipteryx, **504,** 533, 534.
Diptychandra, 501.
Dipyrena, 1040.
Dirca, **1172,** 1178.
Dirichletia, 775.
Dirioneae, 232.
Disanthus, **584,** 592.
Discalacoideae, 366.
Discaria, 411, **412,** 413.
Dischidia, 924.
Dischisma, 1030.
Disciphania, 57.
Discocalyx, 871.
Discocarpus, 1234, 1235.
Discoglypremna, 1235.
Discolobium, 533.
Discophora, 376.
Discopodium, 977.
Disepalum, 49.
Disparago, 803.
Dissilaria, 1235.
Dissochaeta, 648.
Dissomeria, 127.
Dissotis, 648.
Distemonanthus, 501.
Disterigma, 827.
Distichostemon, 430.
Distictella, 1011.
Distribution, geographical, 1354–7.
Distylium, **590,** 592.
Dita Bark, 915.
Ditaxis, 1234.
Divided xylem, 1343.
Dizygotheca, 722, **728,** 735.
Dobera, **902,** 903.
Dobinea, 461.
Dobineae, 459.
Dodecatheon, 862.
Dodonaea, 430.
Doerpfeldia, **408,** 413.
Dogwood, 741.
Dolia, **962,** 964.
Dolichandrone, 1011.
Dolicholobium, 775, 776.
Dolichos, 533.
Dolichothele, 705.
Doliocarpus, 11.
Domatia in leaves, 763.
Dombeya, **250,** 253.
Dombeyeae, 252.
Donatia, 807.
Doona, 220.
Doratoxylon, 430.
Dorisia, 776.
Doronicum, 803.
Dorothy Perkins Rose, 543.
Dorstenia, 1270.
Dorstenieae, 1269.
Dorycnium, 533.
Doryphora, **1140,** 1144, **1148.**
Douglasia, 862.
Dovyalis, **118, 120,** 127.
Downingia, 821.
Doxantha, 1011.
Draba, 87.
Dracaena, 819, 1194.
Dracocephalum, 1052.
Dracontomelum, 461.
Dracophyllum, **838,** 847.
Drapetes, 1178, 1181.
Drepananthus, 49.
Drepanocarpus, 533, 534.
Drepanostemma, 924.
Driessenia, 648.
Drimycarpus, 461.
Drimys, **20,** 25, 29, **32.**
Drosera, **582, 584,** 585.
Droseraceae, 581–5, 586, 1111.
Drosophyllum, **582, 584,** 585.
Druses (in wood), l, 158, 174, 177, 180, 187, 197, 217, 231, 237, 355, 617, 618, 703, 1118, 1193, 1221, 1225, 1227, 1251, 1252.
Dryandra, **1164,** 1168.
Drymonia, 1002.
Dryobalanops, 220.
Drypetes, **1216, 1218,** 1234, 1235.
Drypetinae, 1219, 1229.
Drypis, 152, 721.
Duabanga, **662,** 664.
Duboisia, **966, 970,** 977, 978.
Duboscia, 262.
Duckeodendron, 973.
Ducts, latex, *see* Canals, latex, 1349.
Duguetia, **46,** 49.
Dumasia, 533.
Dunalia, 977, 978.
Dunbaria, 533.
Duranta, 1040, 1041.
Durian, 241.
Durio, **224, 240,** 241, **244.**
Durioneae, 235, 237, 238, 239, 241, 252.
Duroia, 775, 776.
Dussia, 534.
Dye, Annatto, 113.
Dyera, 917.
Dysophylla, 1052.
Dysoxylum, 357, 358.
Dysphania, 152.
Dyssochroma, 977.

Eaglewood, 1173.
East Indian Walnut, 486.
Ebenaceae, 880–6.
Ebenus, 533.
Ebermaira, 1023.
Ebony, 886.

Ebony, Brown, 533.
— Green, 533.
— imitation, 385.
Ecastophyllum, 534.
Ecballium, **688**, 691.
Ecbolium, 1023.
Eccremocarpus, **1006**, 1011.
Ecdysanthera, 917.
Echeveria, 581.
Echieae, 949.
Echinacanthus, 1023.
Echinacea, 803.
Echinocactus, 705.
Echinocarpus, 266.
Echinocereus, 705.
Echinocystis, 691.
Echinofossulocactus, 705.
Echinopanax, 735.
Echinophora, **716**, 724.
Echinops, 803.
Echinopsilon, 1084.
Echinopsis, **700.**
Echinopterys, 285.
Echites, **906**, 917.
Echitoideae, *see* Apocynaceae-Echitoideae, 913.
Echium, **950**, **952**, 954.
Ecological anatomy, 19, 104, 148, 415, 797, 812, 833, 855, 907, 922, 1051, 1057, 1083, 1175, 1228, 1288, 1304, 1319.
Edgeworthia, 1178.
Eganthus, 366.
Egg Plant, 974.
Egyptian Fig, 1269.
Ehretia, **952**, 954.
Eichleria, 303.
Ekebergia, 357, 358.
Ekki, 338.
Ekmanianthe, 1011.
Elaeagia, 776.
Elaeagnaceae, 1184–8, 1305.
Elaeagnus, **1180**, **1186**, 1188, 1305.
Elaeocarpaceae, 260, 261, [262–6.
Elaeocarpeae, 266.
Elaeocarpus, **264**, 266, **270.**
Elaeodendron, **392**, 397.
Elaphrium, 349.
Elateriospermum, **1224**, 1235.
Elatinaceae, 147, 163–5.
Elatine, 165.
Elder Tree, 757.
Eleiotis, 533.
Elephantopus, 803.
Elephantorrhiza, 487.
Eleutherandra, 127.
Eliaea, 169.
Elizabetha, 501.
Ellatostachys, **426**, 430.
Elliottia, 836.
Ellipanthus, 476.
Ellipeia, 49.
Ellisia, 945.
Ellisiophyllum, 945.
Elm, 1277.
Elmerrillia, **20**, 21.
Elsholtzia, **1046**, 1052.
Els, Red, 564.
Elutheria, 358.
Elvasia, 338.
Elytranthe, **1180**, 1194.
Elytraria, 1023.
Elytropappus, 803.
Embelia, 871.
Embothrium, **1166**, 1168.
Emex, 1100.
Emilia, 803.
Emmenanthe, 945.
Emmenopterys, **764**, 775, 776.
Emmenosperma, 411, 413.
Emmeorhiza, 775.
Emmotum, 376.
Emorya, 932.
Empetraceae, 1323–4.
Empetrum, **1318**, **1324**, 1324.
Empleurum, 316.
Enallagma, **1008**, 1013.
Enantia, 49.
Enchylaena, 1084.
Endiandra, 1155.
Endlicheria, 1155.
Endodermis, xix.
Endodermis, casparian thickenings in, 6, 196, 198, 304, 418, 642, 651, 759, 761, 765, 766, 788, 797, 813, 814, 857, 939, 942, 972, 981, 1019, 1033, 1048, 1055, 1056, 1073, 1123, 1183, 1187, 1258, 1325.
Endodermis, chloroplasts in, 959, 1081.
Endodermis, in stem, conspicuous, 83, 101, 105, 150, 155, 164, 167, 173, 189, 294, 304, 404, 492, 541, 586, 596, 597, 601, 637, 642, 665, 710, 765, 766, 777, 780, 788, 798, 806, 813, 814, 817, 833, 844, 860, 918, 919, 935, 937, 939, 942, 943, 944, 969, 972, 981, 999, 1019, 1048, 1057, 1065, 1069, 1081, 1095, 1117, 1123, 1183, 1325.
Endonema, 1183.
Endosperminae, 1231.
Endospermum, **1226**, 1235.
Endusa, 366.
Engelhardtia, **1286**, 1290.
Englerodaphne, 1178.
Englerodoxa, **826**, 827.
English Mandrake, 691.
Enhydra, 803.
Enicostema, 939.
Enkianthus, **824**, 836.
Enkleia, 1178.
Entada, **482**, 487, **536.**
Entadopsis, 487.
Entandrophragma, 357, 358.
Entelea, 262.
Enterolobium, 487.
Epacreae, 843.
Epacridaceae, 835, 840–7.
Epacris **842**, 847, **848.**
Eperua, **494**, 501.
Ephedroid perforation plates, xli, 294.
Epicharis, 357, 358.
Epidermal cells, diagnostic characters of, xv.
Epidermal cells of leaf horizontally divided, 1331.
Epidermal cells of leaf vertically divided, 1331.
Epidermis, crystals in, 11, 37, 45–6, 54, 59, 91, 110, 117, 273, 287, 288, 289, 309, 490, 502, 510, 511, 844, 865, 907, 966, 993, 1019, 1025, 1035, 1060–1, 1076, 1122, 1129, 1203, 1263.
Epidermis sclerotic, 53, 95, 134, 173, 421, 717, 721, 896, 1179, 1212.
Epigaea, 836.
Epigynum, 917.
Epilobium, 667, 668.
Epimedium, 63, **66.**
Epiphyllum, 705.
Epirrhizanthes, 138.
Episcia, 1002.
Epithema, 1002.
Equisetum, 1294, 1301.
Eranthemum, **1020**, 1023.
Erblichia, 674.
Ercilla, 1091.
Eremaea, 630.
Eremanthus, 803.
Eremobium, 87.
Eremocarpus, 1234.
Eremochlaena, 223.
Eremocitrus, 316.
Eremocordia, **946.**
Eremopanax, 735.
Eremophila, **1020**, 1027.
Eriandrostachys, 430.
Eribroma, 253.
Erica, **824**, 836.
Ericaceae, 822, 825, 827–36, 839, 840, 841, 847, 849, 850.
Ericales, 835, 850.
Ericameria, 803.
Ericeae, 829.
Ericoid leaves, 8, 131, 145, 798, 827, 1169.
Erigeron, **788**, 803.
Erinacea, 533.
Erinocarpus, 262.
Erinus, 988.
Eriobotrya, **542**, 549.
Eriocephalus, 803.
Eriocoelum, 430.
Eriodendron, 241.
Eriodictyon, 833, 850, 945.
Erioglossum, 430.
Eriogonoideae, 1093.

Eriogonum, 1100.
Eriolaena, **250,** 253.
Eriolaeneae, 252.
Eriolobus, 549.
Eriope, 1052.
Eriosema, 533.
Eriosolena, 1178.
Eriostemon, 316.
Erioxylum, 233.
Erisma, 142, **144.**
Erismadelphus, 142.
Erismanthus, 1234.
Erithalis, 775, 776.
Eritricheae, 949.
Eritrichium, 954.
Erlangea, 803.
Ernestia, 648.
Ernodea, 775.
Erodium, **296,** 297.
Eruca, 87.
Ervatamia, **910,** 917.
Erycibe, 964.
Eryngium, 148, **714, 718,** 724.
Erythrina, **504, 520,** 533, 534.
Erythrochiton, 316.
Erythrococca, 1234.
Erythrophleum, 501.
Erythrophyxa, 430.
Erythrospermum, 127, 1230.
Erythroxylaceae, 137, 271, 273–7, 284.
Erythroxylum, **270, 276,** 277.
Escallonia, **556, 558,** 568.
Escalloniaceae, 131, 555, 565–8, 573, 577.
Eschscholtzia, 78.
Eschweilera, **634,** 636.
Esenbeckia, 316.
Espadaea, 1041.
Espeletia, 803.
Etaballia, 534.
Ethulia, 803.
Etiolated shoots of Cactaceae, 703.
Euartocarpeae, 1269.
Eucalyptus, **622, 624, 628,** 630.
Eucalyptus Oil, 629.
Eucarya, **1198,** 1201.
Eucassineae, 395.
Eucelastreae, 395.
Euceraea, 127.
Euchaetis, 316.
Eucharidium, 667.
Euchlora, 533.
Euchresta, 533.
Euclea, **884,** 886.
Euclinia, 776.
Eucnide, 669, **670.**
Eucommia, **14, 32,** 34, 1229.
Eucommiaceae, 31–4, 42, 1229.
Eucrotoneae, 1216.
Eucryphia, **562, 570,** 571.
Eucryphiaceae, 10, 564, 568–71.
Eugenia, **624, 626,** 630.
Eumimoseae, 479.
Eumorphanthus, 776.
Euonymus, **382, 392,** 397.
Eupatorieae, 783.
Eupatorium, **790, 792,** 803.
Euphorbia, 33, 430, 985, 1234, 1235.
Euphorbiaceae, 315, 332, 348, 361, 800, 914, 1207–35, 1242, 1252, 1270.
Euphorbias, 1207, 1208, 1209, 1213, 1214, 1217, 1229.
Euphorbieae, 1212, 1215, 1225.
Euphorbium, 1233.
Euphorianthus, 430.
Euphrasia, 988.
Euphyllantheae, 1212.
Eupomatia, **48,** 51, **54.**
Eupomatiaceae, 50–1, 1137.
Euptelea, 36, **40.**
Eupteleaceae, 34–6.
European Ash, 899.
European Holly, 385.
European Lime, 261.
Euroschinus, 461.
Eurotia, **1072, 1076,** 1084.
Eurya, 190, 191.
Euryale, 71.
Eurycoma, **318,** 325.
Eurycomineae, 320.
Eurylobium, 1040.
Euscaphis, **444,** 447.
Eusideroxylon, **1150,** 1155.
Eustigma, 592.
Eustoma, 939.
Eutaxia, 533.
Euthemis, 338.
Euxylophora, **312,** 316.
Evax, 803.
Eversmannia, 533.
Evodia, 316.
Evolvulus, **956,** 964.
Exacum, **934,** 939.
Exalbuminosae, 219, 333, 338.
Excavatia, 917.
Excoecaria, **1226,** 1234, 1235.
Exocarpus, **1198,** 1201.
Exochorda, 549.
Exodermis, contractile, 5, 1038.
Exogonium, 964.
Exomis, 1084.
Exospermum, 29.
Exostema, 775, 776.
Exothea, 430.
Extra-floral nectaries, 139, 140, 196, 200, 213, 225, 236, 243, 297, 317, 318, 506, 539, 540, 684, 685, 701, 752, 753, 822, 881, 894, 895, 926, 957, 980, 1030, 1031, 1093, 1094, 1208, 1209.
Eysenhardtia, 533, 534.

Fabiana, **968,** 977, 978.
Fadogia, 775.
Fagaceae, 1289, 1290, 1309–15.
Fagales, 466.
Fagara, **312,** 316.
Fagelia, **504, 505,** 533.
Fagonia, **286,** 292.
Fagopyrum, **1096,** 1100.
Fagraea, **930,** 932.
Fagraeae, 931.
Faguetia, 461.
Fagus, 1289, **1306, 1312,** 1315.
Falcaria, 724.
Falkia, 964.
Fallugia, 549.
Families, evolution of, xxx.
Families, sequence of, lv.
Faramea, 775, 776.
Fascicular cambium, xxxiii.
Fatoua, 1270.
Fatoueae, 1269.
Fatshedera, **728,** 735.
Fatsia, **728,** 735.
Faucaria, 711.
Faujasia, **792,** 803.
Faurea, **1166,** 1168.
Fawcettia, 57.
Fedia, 779.
Feijoa, 630.
Felicia, 803.
Fendlera, 577.
Fenestraria, 711.
Fennel, 724.
Ferdinandusa, 775, 776.
Feretia, 775, 776.
Fernelia, 775, 776.
Feronia, 316.
Ferula, 724.
Fevillea, 691.
Fibres, crystals in, 64, 65, 514, 767, 875, 921, 1183, 1292, 1297, 1304, 1317.
Fibres in cortex, 134, 204, 288, 391, 403, 513, 541, 597, 721, 896, 919, 1019, 1217.
Fibres in mesophyll, 45, 117, 143, 157, 180, 205, 279, 287, 369, 375, 420, 421, 476, 480, 491, 588, 612, 613, 621, 632, 865, 873, 891, 907, 919, 948, 957, 1032, 1133, 1139, 1170, 1176, 1181, 1182.
Fibres in pith, 227, 302, 730, 883, 921, 1097, 1217.
Fibres (in wood):
  bordered pits conspicuous, xviii, xlv, 1351.
  cambiform, 1174.
  crystalliferous, 248, 265, 313, 347, 475, 618, 654, 659, 885, 912, 1027, 1099, 1222, 1242, 1252.
  in rays, 525.
  length, xxvii, 1361.
  parenchyma-like, 497.

Fibres (in wood):
  septate, xlvi, xlvii, 1351.
  septate, with parenchyma-like distribution, 394, 401, 429, 458, 475, 485, 647, 654, 1099.
  spirally thickened, 1352.
  storied, 1352.
Fibres, multinucleate, 974.
Fibriform vessel members, 13, 393, 678.
Ficalhoa, 836.
Ficaria, 5.
Ficeae, 1269.
Ficoidaceae, 706–12.
Ficus, **1248**, **1262**, 1270.
Fig, Egyptian, 1269.
Fiji Sandalwood, 1201.
Filago, 803.
Filbert Nuts, 1309.
Filicium, 430.
Filipendula, **542**, 549.
Fillaeopsis, 487.
Finschia, 1168.
Firmiana, 253.
Fissistigma, 49.
Fittonia, 1023.
Fixation of material, liii.
Flabellaria, 285.
Flacourtia, 127.
Flacourtiaceae, 108, 113, 116–27, 211, 212, 232, 260, 261, 395, 673, 679, 1177, 1181, 1230, 1319, 1322.
Flacourtiaceae - Paropsieae, 126.
Flaveria, 803.
Flavone (in wood), 1038.
Flax, 272, 1257.
Flemingia, 533.
Flindersia, **312**, 316, **350**, 356.
Flindersiaceae, 314.
Floerkea, 299.
Florida Grapefruit, 308.
Flotovia, 803.
Flourensia, **792**, 803.
Flowering plants, origin of, xxx.
Foeniculum, **714**, **716**, 724.
Foetidia, 636.
Foliar ray hypothesis, xxxvii.
Folotsia, 924.
Fontainea, 1235.
Fontanesia, 900.
Foraminate perforation plates (in wood), xli, 122, 201, 311, 433, 451, 545, 825, 1006, 1238.
Forchammeria, **92**, 94, 95.
Forestiera, **894**, 900.
Forgesia, 568.
Forskohleae, 1247, 1249.
Forstera, 807.
Forsteronia, 917.
Forsythia, **898**, 900.
Fortunearia, **584**, 592.
Fortunella, 316.
Fothergilla, 592.
Fouquiera, **144**, 159, **160**, 163.
Fouquieraceae, 159, 159–63.
Foxglove, 986.
Fragaria, 549.
Francoa, 557.
Frangula, 411, **412**.
Frankenia, **130**, **146**, 147.
Frankeniaceae, 145–7, 158, 164.
Frankincense, 348.
Franklandia, **1162**, 1168.
Franklinia, 190, 191.
Fraunhofera, 397.
Fraxinus, **888**, **898**, 900.
Fredolia, 1084.
Fremontia, **250**, 253.
Freylinia, 988.
Freziera, **182**, **186**, 190.
Fridericia, 1011.
Frithia, 711.
Fritzschia, 648.
Froelichia, **1062**, 1074.
Fropiera, 127.
Fuchsia, **658**, **662**, 667, 668.
Fucus, 1101.
Fugosia, 233.
Fumana, 102.
Fumaria, **76**, 79.
Fumariaceae, 78, 78–9.
Funifera, 1178.
Funtumia, **910**, 917.
Fusanus, 1201.
Fusarium, 233.
Fusiform parenchyma cells (in wood), *see* Parenchyma.

Gaboon Mahogany, 142, 349.
Gaboon Nut, 366.
Gaertnera, **766**, 775, 776.
Gagnebina, 487.
Gaiadendron, 1194.
Gaillardia, 803.
Gaillonia, 775.
Galactia, 533.
Galactites, 803.
Galageae, 505, 508, 516.
Galax, **848**, 850.
Galbanum, 723.
Galearia, 1235.
Galeariinae, 1231.
Galega, 533.
Galenia, 711.
Galeopsis, **1046**, 1052.
Galieae, 761, 765.
Galiniera, 775, 776.
Galinsoga, 803.
Galipea, 316.
Galium, **764**, 775.
Gallesia, **1088**, 1091.
Galls, Tamarix, 158.
Galopina, 775.
Galphimia, **270**, 285.
Galpinia, 654.
Gamblea, 735.
Gambo Hemp, 233.
Ganophyllum, 430.
Garcia, 1235.
Garcinia, **166**, **172**, **174**, 178, 179.
Garcinieae, 171, 177, 178.
Gardenia, **764**, **766**, 775, 776.
Gardneria, 932.
Gardoquia, 1052.
'Garlic Bark', 889.
Garrya, **742**, **746**, 748.
Garryaceae, 745–8.
Garuga, 349.
Gaslondia, 630.
Gastonia, 735.
Gastrolepsis, 376.
Gastrolobium, 533.
Gaudichaudia, 285.
Gaultheria, **824**, **826**, 836.
Gaultherieae, 829.
Gaura, 668.
Gavarretia, **1224**, 1235.
Gaylussacia, **824**, 827.
Gayophytum, 668.
Gazania, 803.
Geijera, 316.
Geissaspis, 533.
Geissois, 564.
Geissoloma, 1184.
Geissolomataceae, 1183–4.
Geissomeria, 1023.
Geissospermum, 917.
Gelonieae, 1223, 1225, 1227, 1231.
Geloniinae, 1231.
Gelonium, 1234, 1235.
Gelsemium, 932.
Genetics, taxonomic value of, xi.
Geniculate crystals, 55, 197, 198.
Geniosporum, 1052.
Geniostemon, 939.
Geniostoma, 932.
Genipa, 775, 776.
Genista, 533, 534.
Genisteae, 509.
Genlisea, **992**, 994.
Gentiana, **934**, 939.
Gentianaceae, 933–9.
Gentianoideae, 933, 936, 938, 942.
Gentian Root, 1023.
Geoffraea, 533, 534.
Geographical distribution, 1354–7.
Geraniaceae, 292–7, 298, 299, 303, 305, 324, 579.
Geraniales, 446.
Geranium, **296**, 297.
Geranium Oil, 292, 297.
Gerardia, 988.
Gerbera, 803.
Gerrardanthus, 691.
Gerrardina, **118**, 127.
Gesneria, **1000**, 1002.
Gesneriaceae, 995, 995–1002.
Geum, 549.

Geunsia, 1041.
Giant nuclei, 689, 1206.
Gibbaeum, 711.
Gilia, **940**, 942.
Gillenia, 549.
Gillespiea, 776.
Ginkgoales, 29.
Ginora, 654.
Ginseng, 734.
Gironniera, 1278.
Gisekia, 711.
Givotia, 1234, 1235.
Glandonia, 285, **290**.
Glands, chalk, 1326.
Glands, pearl, 1326.
Glands, salt, 1326.
Glands, sessile or shortly stalked, 1328.
Glands, snail-shaped, 1326.
Glands, with long or fairly long stalks, 1329.
Glaucidium, 7.
Glaucium, 78.
Glaux, **860**, 862.
Glaziova, 1011.
Gleasonia, 776.
Glechoma, **1046**.
Gleditschia, **494**, 501.
Glenica, 430.
Glinus, **708**, 711.
Gliricidia, 534.
Glischrocolla, 1183.
Glischrothamnus, 711.
Globe Artichoke, 799.
Globularia, **1026**, 1030.
Globulariaceae, *see* Selaginaceae and Globulariaceae.
Glochidia, 698, 699.
Glochidiinae, 1213, 1219, 1221, 1230.
Glochidion, 348, **1220**, 1234, 1235.
Glochidion type (of wood), 1208, 1221, 1223, 1230, 1231.
Glockeria, 1023.
Gloeospermum, 108.
Glossocalyx, 1144.
Glossochilus, 1023.
Glossolepis, 430.
Glossonema, 924.
Glossopetalum, 397.
Glottiphyllum, 711.
Gloxinia, **998**, 1002.
Gluta, **456**, 461.
Glycine, 533.
Glycosmis, 316.
Glycyrrhiza, 533.
Glyphaea, 262.
Glyptopetalum, 397.
Gmelina, 1041.
Gnaphalinae, 795.
Gnaphalium, 803.
Gnetales, 295.
Gnidia, 1178.
Gochnatia, 803.
Godetia, 668.
Godmania, **1008**, 1013.
Godoya, 338.
Goethalsia, 262.
Goethea, 233.
Goetzea, 977.
Goldbachia, 87.
Goldenrods, 802.
Goldfussia, **1012**, 1023.
Gomidesia, 630.
Gomortega, 1157.
Gomortegaceae, 1156–7.
Gomphia, **334**, 338.
Gomphocarpus, 924.
Gompholobium, 533.
Gomphostemma, 1052, 1053.
Gomphostigma, **926**, 932.
Gomphrena, 1074.
Gongrodiscus, 430.
Gongronema, 924.
Gongylocarpus, 668.
Goniolimon, 857.
Gonioma, 917.
Goniorrhachis, 501.
Goniothalamus, 49.
Gonocaryum, **368**, 376.
Gonolobus, 924.
Gonypetalum, 361.
Gonystylaceae, 1178–81.
Gonystyloideae, 1179.
Gonystylus, **1180**, 1181.
Gonzalagunia, 776.
Gonzalea, 775.
Goodallia, 1178.
Goodenia, 809.
Goodeniaceae, 807–10.
Goodia, 533.
Gooseberries, 573.
Gordonia, **186**, 190, 191.
Gossampinus, 241.
Gossweilerodendron, **494**, 501.
Gossypiospermum, 127.
Gossypium, **228**, 233.
Gossypol, 226.
Gossypol cavities (in wood), 231, 232.
Gouania, 411, 413.
Gouanieae, 406.
Gouldia, 776.
Goupia, **382**, **388**, 395, 399.
Goupiaceae, 395, 397–9.
Goupioideae, 398.
Gourliea, 534.
Grabowskya, **970**, 977, 978.
Graffenrieda, 648.
Graft hybrids, 541, 974.
Gramineous stomata, xv.
Grammadenia, 871.
Gramophone needles, 705.
Grandidiera, 127.
Grangeria, 553.
Grapefruit, Florida, 308.
Grape, Seaside, 1100.
Grape vine, 419, 1200.
Graptophyllum, 1023.
Gratiola, **982**, 988.
Gravesia, 648.
Grayia, **1072**, **1076**, 1084.
Greenea, 775.
Green Ebony, 533.
Greenheart, 1155.
Greenheart, Demerara, 636.
Greenovia, 581.
Grenadillas, 680.
Grevillea, **1162**, **1164**, 1168.
Grewia, **256**, 262.
Greyia, 443.
Greyiaceae, 443.
Grey Sassafras, 1144.
Grias, 636.
Griffithia, 49.
Griffithianthus, **48**, 49.
Grindelia, 803.
Griselinia, 741, **742**.
Grislea, 654.
Grisollea, 376.
Grona, 533.
Gronovia, 669.
Grossera, **1224**, 1235.
Grossulariaceae, 555, 567, 568, 572–3.
Growth rings, xxvii.
Growth rings, development of, 219, 232, 240, 356, 385, 429, 435, 459, 469, 485, 499, 546, 618, 628, 744, 757, 795, 877, 899, 912, 1227, 1239, 1304, 1319.
Grubbia, 1202.
Grubbiaceae, 1202.
Gruinales, 459.
Guaiacum, **270**, **286**, **290**, 292.
Guaiacum Resin, 291.
Guamia, 49.
Guarana Bread, 430.
Guarea, **354**, 357, 358.
Guatteria, 49.
Guava Fruits, 629.
Guayule, 800, 801, 802.
Guazuma, **244**, 253.
Gueldenstaedtia, 533.
Guetardeae, 760.
Guettarda, 775, 776.
Guevina, **1166**.
Guiera, **616**, 620.
Guilfoylia, **322**, 325.
Guioa, 430.
Guizotia, 803.
Gum Arabic, 486.
Gum Benzoin, 887, 889.
Gum, Black, 751.
Gum cysts (in wood), 496.
Gum, Katira, 115.
Gums, 630.
Gums, economic, 253.
Gundelia, 803.
Gunnera, 599, **600**.
Gunnera, *Nostoc* in tissues of, 596, 597.
Gurjun, 220.
Gustavia, **634**, 636, **638**.
Gutta-percha, 879, 915.
Guttiferae, 110, 115, 169, 170–9, 179, 181, 195, 204, 219, 220, 272.

Guttiferae - Calophylloideae, 169.
Guttiferales, 126, 198.
Guyonia, 648.
Gyminda, 397.
Gymnacranthera, **1134**, 1138.
Gymnanthes, 1235.
Gymnartocarpus, 1270.
Gymnema, 924.
Gymnocalycium, 705.
Gymnocarpos, 152.
Gymnocladus, **494**, 501, **536**.
Gymnopetalum, 691.
Gymnopodium, 1100.
Gymnosperms, 29, 1288, 1297.
Gymnosporia, 397.
Gymnostachyum, 1023.
Gynandropsis, 94.
Gynocardia, 127.
Gynostemma, 691.
Gynotrocheae, 602, 610.
Gynotroches, **606**, 611, 612.
Gynura, 803.
Gypsophila, 152, **160**.
Gypsophilas, 152.
Gypsum, 91, 157, 158, 467, 786.
Gyranthera, 241.
Gyrinops, 1178.
Gyrinopsis, 1178.
Gyrocarpus, **1150**, 1159, 1160.
Gyrostemon, **1088**, 1091.
Gyrostemonaceae, 1090.
Gyrotaenia, 1253.

Habit, 1358–9.
Hablitzia, 1084.
Habracanthus, 1023.
Habrosia, 152.
Habzelia, 49.
Haematostaphis, 461.
Haematoxylon, 501, **536**.
Haemocharis, 191.
Haemanthus, 900.
Hagenia, 549.
Hairs, arachnoid, 1326.
Hairs, bladder-like, 1326.
Hairs, branched, 1328.
Hairs, calcified, 1327.
Hairs, dendritic, 1328.
Hairs, diagnostic value of, xiv.
Hairs, exclusively unicellular or uniseriate, 1329.
Hairs, families with numerous types of, 1327.
Hairs, glandular shaggy, 1327.
Hairs, laticiferous, 1326.
Hairs, mucilage, special type of, 1326.
Hairs, non-glandular, shaggy, 1327.
Hairs, non-glandular, tufted, 1327.
Hairs, peltate, 1329.
Hairs, silicified, 1327.
Hairs, stellate, 1328.
Hairs, stinging, 1326.
Hairs, two-armed or T-shaped, 1327.
Hairs, types of, 1326–9.
Hairs, vesicular, 1326.
Hakea, **1162**, **1164**, 1168.
Halenia, 939.
Halesia, **888**, 890, **898**.
Halfordia, **312**, 316.
Halgania, 954.
Halimium, 102.
Halimocnemis, 1084.
Halimodendron, 533, 534.
Halleria, **982**, 988, **1000**.
Hallia, 533.
Halocnemum, 1084.
Haloragaceae, 596–9, 601, 1258.
Haloragis, **598**, 599.
Halostachys, 1084.
Haloxylon, 1084.
Hamamelidaceae, 30, 34, 211, 212, 327, 587–93, 594, 1242, 1281. [1119.
Hamamelidales, 25, 31, 211,
Hamamelidoideae, 588, 589.
Hamamelis, **584**, **590**, 592.
Hamelia, 775, 776.
Hamiltonia, 775.
Hammatolobium, 533.
Hampea, 241.
Hanburia, **686**, 691.
Hancornia, 917.
Hannoa, **322**, 325.
Haplanthus, 1023.
Haploclathra, 178, 179.
Haplocoelum, 430.
Haplolophium, 1011.
Haplopappus, 803.
Haplormosia, 534.
Haplostephium, 803.
Hardenbergia, 533.
Hard Maple, 435.
Hard Pear, 657.
Hardwickia, 501.
Harfordia, 1100.
Harmsiopanax, 735.
Harpalyce, 533, 534.
Harpephyllum, 461.
Harpochilus, 1023.
Harpullia, 430.
Harrisia, 705.
Harrisonia, 325.
Hartogia, 397.
Harungana, 169, **176**.
Hasseltia, 127.
Hasseltiopsis, 127.
Hatiora, 705.
Haustoria, 69, 985, 986, 988, 990, 1188, 1194, 1195, 1200, 1203, 1206.
Hauya, 668.
Havetia, 178.
Havetiopsis, 178, 179.
Hawaiian Sandalwood, 1201.
Haya, 152.
Haynaldia, 821.
Hazel, Common, 1309.
Hearnia, 357.
Heaths, 835.
Hebecoccus, 430.
Hebenstretia, **1026**, 1030.
Hebepetalum, 273.
Hebestigma, 534.
Hebonga, 325.
Hecatostemon, 127.
Hectorella, 156.
Hedeoma, 1052. [990.
Hedera, **726**, **728**, **732**, 735,
Hedraeanthus, 816.
Hedstromia, 776.
Hedwigia, 349.
Hedycarya, **1140**, 1144.
Hedyosmum, **1130**, 1132.
Hedyotis, 775.
Hedysareae, 505, 508, 513.
Hedysarum, 533.
Heeria, 461, 648.
Heimia, 654.
Heinsia, 775, 776.
Heisteria, 366.
Helenieae, 783.
Helenium 803.
Heliamphora, 74.
Heliantheae, 783.
Helianthemum, **98**, 102.
Helianthostylis, 1270.
Helianthus, **788**, 803.
Helichrysum, 803.
Helicia, 1168.
Helicostylis, 1270.
Helictereae, 252.
Helicteres, 253.
Helietta, 316.
Helinus, 411.
Heliocarpus, **256**, 262.
Heliophila, 87.
Heliopsis, 803.
Heliotropium, **950**, 954.
Helipterum, 803.
Hellebore, Black, 6.
Helleborus, **2**, 7.
Helminthocarpum, 533.
Helosidoideae, 1205.
Helosis, 1207.
Helwingia, 741, **742**.
Hemandradenia, 476.
Hemiandra, 1052.
Hemiangium, 403.
Hemiboea, 1002.
Hemichroa, 1084.
Hemidesmus, 924.
Hemidiodia, 775.
Hemigenia, 1052.
Hemigyrosa, **426**, 430.
Hemiphragma, 988.
Hemisantiria, 349.
Hemp, 272.
Hemp, Chinese, 233.
— Deccan, 233.
— Gambo, 233.
— Indian, 233.

Hemp, Queensland, 233.
— Rozelle, 233.
— Sunn, 529.
Hemp fibre, 1256.
Hemp seeds, 1257.
Henna, 654, 954.
Henoonia, 977.
Henriettea, 648.
Henriettella, 648.
Henriquezia, **768**, 775, 776.
Henslowia, 1201.
Hepatica, 7.
Heptacyclum, 57.
Heptapleurum, 735.
Heracleum, 724.
Herbarium specimens, liii.
Herbs and trees, origin of, xxxii.
Herbs, types of, xxxix.
Heritiera, **224**, **244**, **246**, 253.
Hermannia, 253.
Hermannieae, 252.
Hermas, 724.
Hermbstaedtia, 1074.
Hermidium, 1067.
Herminiera, 533.
Hernandia, **1150**, 1159, 1160.
Hernandiaceae, 111, 1137, 1143, 1157–60.
Herniaria, 152.
Herpestis, 988.
Herpetacanthus, 1023.
Hesperethusa, 316.
Hesperidin, 309, 319, 384, 715, 1042, 1045, 1050.
Hesperis, **80**.
Heteranthia, 977, 986.
Heterochaenia, 816.
Heterodendron, 430.
Heteromeles, 549.
Heteromorpha, **718**, 724.
Heteropanax, 735.
Heteropetalum, 49.
Heterophragma, 1013.
Heterophyllaea, 775.
Heteropteris, **270**, 285.
Heteropyxidaceae, 651.
Heteropyxis, 649, 651.
Heterostemon, 501.
Heterotoma, 821.
Heterotrichum, 648.
Heuchera, **556**, 557.
Hevea, 800, **1226**, 1234, 1235, 1270.
Hewittia, 964.
Hexalobus, 49.
Heylandia, 533.
Heynea, 358.
Hibbertia, **8**, 11, **12**, 38.
Hibbertieae, 8.
Hibisceae, 225, 230, 232.
Hibiscus, **228**, 233, 236, 240, **244**.
Hickory wood, 1290.
Hicksbeachia, 1168.
Hieracium, 803.
Hierobotana, 1040.
Hieronyma, 1234, 1235.
Hilairella, 338.
Hildebrandtia, 964.
Hilleria, 1091.
Hillia, 775.
Himantandra, **14**, 38, **40**.
Himantandraceae, 16, 36–8, 42.
Himantochilus, 1023.
Himatanthus, 917.
Hindsia, 775.
Hippobromus, 430.
Hippocastanaceae, 347, 429, 439–41, 451.
Hippocratea, **388**, 403.
Hippocrateaceae, 399–403.
Hippocrepis, 533.
Hippomane, 1234, 1235.
Hippomaneae, 1209, 1212, 1215, 1223, 1225, 1227, 1231.
Hippophaë, **1180**, 1188.
Hippotis, 775, 776.
Hippuridaceae, 600–1.
Hippuris, **598**, **600**, 601, 1258.
Hiptage, **270**, 285.
Hiraea, **280**, 285.
Hirtella, 553.
Hisingera, 127.
Hoarhound, adulterant in, 1052.
Hockinia, 939.
Hodgkinsonia, 776.
Hoffmannia, 775.
Hoffmanseggia, 501.
Hofmeisteria, 803.
Hoheria, **228**, 233.
Holacantha, 325.
Holacanthaceae, 325.
Holarrhena, 917.
Holarrhena Bark, 915.
Holboellia, 66, 67.
Holigarna, 461.
Hollisteria, 1100.
Hollrungia, 680.
Holly, 385.
Hollyhocks, 233.
Holmskioldia, 1040.
Holocalyx, **494**, 501.
Holocarpa, 775.
Holodiscus, 549.
Hololachne, 159.
Holoptelea, **1276**, 1278.
Holostylis, 1119.
Holtonia, 776.
Homalanthus, 1235.
Homalium, **118**, **120**, 127, 1230.
Homogeneous rays (in wood), xxv.
Homonoia, 1234, 1235.
Honckenya, 152.
Honduras Rosewood, 533.
Honey Locust, 486.
Hoodia, 924.
Hopea, **214**, **216**, 220.
Hopelstigma, 127.
Hop Hornbeam, 1309.
Hops, 1256.
Horminum, **1044**, 1052.
Hornbeam, Common, 1309.
— Hop, 1309.
Hornea, 430.
Hornschuchia, 49.
Horse Chestnut, 441.
Horse-radish, 86.
Horse-radish Tree, 471.
Horsfieldia, 735, **1134**, 1138.
Hortia, 316.
Hortonia, 1144.
Hosackia, 533.
Hosiea, 376.
Hoslundia, 1052, 1053.
Hoteia, 557.
Hottonia, 862.
Houstonia, 775.
Houttuynia, **1124**, 1128.
Hovea, 533.
Hovenia, 411, 413.
Hoya, 924.
Hua, 253.
Huanuco Coca, 275.
Huberia, 648.
Huberodendron, 241.
Hudsonia, 102.
Huertea, 447.
Hufelandia, 1155.
Hugonia, 273.
Humbertia, 964.
Humboldtia, **490**, 501.
Humea, 803.
Humiria, 279.
Humiriaceae, 137, 271, 272, 277–9, 284.
Humirianthera, 376.
Humulus, **1254**, 1257, **1274**.
Hunteria, 917.
Huodendron, 890.
Hura, 1234, 1235.
Husemannia, 57.
Hyalis, 803.
Hyalocalyx, 674.
Hybanthus, 108.
Hybrids, graft, 541.
Hydathodes, 3, 53, 69, 75, 117, 183, 225, 263, 297, 298, 300, 304, 368, 540, 554, 559, 579, 613, 693, 758, 777, 787, 805, 811, 812, 813, 859, 937, 980, 986, 987, 989, 990, 1003, 1013, 1039, 1044, 1055, 1077, 1094, 1105, 1121, 1122, 1244, 1245, 1261, 1279, 1310, 1333.
Hydnocarpus, 127.
Hydnophytum, 775.
Hydnora, 1113.
Hydnoraceae, 1113.
Hydrangea, **556**, **576**, 577.
Hydrangeaceae, 327, 555, 568, 573–7, 740.
Hydrastis, 63.
Hydrobryum, 1104.

Hydrocotyle, 724.
Hydrolea, 945.
Hydrophyllaceae, 833, 943–5.
Hydrophyllum, **940**, 945.
Hydrostachyaceae, 1104.
Hydrostachys, 1104.
Hygrocharis, 964.
Hygrophila, 1023.
Hymenaea, 501.
Hymenandra, 871.
Hymenanthera, **100**, 108.
Hymenocardia, 1234, 1235.
Hymenocarpos, 533.
Hymenoclea, 803.
Hymenocrater, 1052.
Hymenodictyon, **768**, 775, 776.
Hymenolobium, 534.
Hymenonema, 803.
Hymenopogon, 775.
Hymenosporum, 131.
Hymenostegia, 501.
Hymenoxys, 803.
Hyoscyamus, 976, 977.
Hyoscyamus, 977.
Hyoseris, 803.
Hypelate, 430.
Hyperbaena, 57.
Hypericaceae, 165–9, 178, 272, 557.
Hypericopsis, 147.
Hypericum, **166**, 169, **176**.
Hypertelis, 711.
Hyphae, fungal, in roots, 5, 291.
Hypobathrum, 776.
Hypocalyptus, 533.
Hypochoeris, **784**.
Hypodaphnis, **1150**, 1155.
Hypodermis, in leaf, xv, 1331.
Hypopitys, 840.
Hypseocharis, 303.
Hypsipodes, 57.
Hyptiandra, 325.
Hyptianthera, 775.
Hyptis, 1053.
Hyssopus, 1052.
Hytiodaphne, 1178.

Ibadja, 501.
Iberis, **84**, 87.
Icacina, 376.
Icacinaceae, 365, 367–77, 381, 1230.
Icacineae, 370, 371, 374, 375.
Icacinoideae, 369, 370, 375.
'Ice-plants', 706.
Ichnocarpus, 917.
Ichthyomethia, 534.
Idesia, **120**, 127, 679.
Idigbo, 619.
Idioblasts, crystal, 117, 125, 126, 193, 215–94, 390, 391, 400, 431, 432, 537, 612, 651, 659, 780, 907, 927, 945, 958, 1202, 1208, 1214, 1242, 1258, 1263, 1307.
Idioblasts (in wood), 283, 289, 311, 394, 427, 617, 618, 868, 869, 971, 972, 1308.
Idioblasts, sclerenchymatous, development of, 184.
Idioblasts, sclerenchymatous (spicular cells), 8, 9, 17, 26, 35, 39, 41, 42, 45, 52, 53, 67–8, 69, 90, 117, 124, 146, 182, 183, 184, 185, 190, 194, 196, 197, 199, 200, 201, 203, 204, 205, 211, 226, 236, 267, 269, 273, 278, 317, 319, 335, 339, 341, 343, 344, 351, 362, 363, 389, 390, 509, 537, 551, 561, 587, 588, 592, 601, 603, 604, 609, 610, 657, 660, 661, 663, 671, 675, 693, 694, 695, 696, 697, 736, 747, 749, 761, 807, 808, 843, 855, 865, 894, 895, 905, 927, 928, 937, 957, 989, 997, 1004, 1029, 1039, 1133, 1160, 1161, 1163, 1259, 1261.
Idioblasts, secretory, 35, 42, 43, 50, 79, 82, 167, 287, 309, 313, 551, 672–3, 805, 806, 981, 1265.
Idria, 163.
Ifloga, 803.
Ilex, 376, **382**, 385, **388**, 774, 834, 871.
Illecebraceae, 148, 149, 151, 152.
Illecebrum, 152.
Illiciaceae, 24.
Illicium, **20**, 25, 28, 29, **32**.
Illigera, 1159.
Illipe, **878**, 879, 880.
Imitaria, 711.
Impatiens, **296**, 298.
Imperfect vessel members, 93, 313.
Incarvillea, **1004**, **1006**, 1011.
Included (interxylary) phloem, xxvii, 1343, 1352.
Indian Almonds, 619.
Indian Birthwort, 1119.
Indian Hemp, 233.
Indian Laurel, 619.
Indian Rosewood, 533.
Indian Sandalwood, 1201.
Indian Sarsaparilla, 924.
Indian Satinwood, 314.
Indian Silver Grey Wood, 619.
Indigo, 502, 511, 529.
Indigo Root, Wild, 531.
Indigofera, 533, 534.
Indorouchera, 273.
Inga, 487, **536**.
Ingeae, 479.
Ingenhouzia, 233.
Inocarpus, 534.
Inophloeum, 1270.
Intercellular canals (in wood), li, 1353.
Interfascicular cambium, xxxiii.
Interfascicular cambium absent, 3, 299.
Interfascicular phloem, 1099.
Interfascicular rays, 93, 401, 524, 1038, 1117.
Interxylary cork, 667, 795, 798.
Interxylary (included) phloem, xxvii, 1343, 1352.
Intraxylary phloem, xiii, 1343.
Intsia, 501.
Intumescences arising from phelloderm, 351.
Inula, 803, 804.
Inuleae, 783, 795.
Iochroma, 977, 978.
Iodeae, 370, 373, 374, 375.
Iodes, 376.
Ionidium, 108.
Ipecacuanha, 357, 773, 1233.
Ipecacuanha root, substitute, 108.
Ipe Peroba, 1011.
Ipomoea, **956**, **958**, **962**, 964, 1067.
Iresine, **1068**, 1074.
Iroko, 1269.
Ironbarks, 630.
Irvingbaileya, 376.
Irvingeae, 318, 319, 320, 324.
Irvingella, 325.
Irvingia, **322**, 325.
Irvingioideae, 324, 325.
Iryanthera, **1134**, 1138.
Isandra, 977.
Isatis, 87.
Isertia, **760**, 775, 776.
Isnardia, 668.
Isoberlinia, 501.
Isodendrion, 108.
Isoglossa, **1020**, 1023.
Isoloma, **998**, 1002.
Isomeris, **92**, 94, 95.
Isopogon, **1162**, 1168.
Isoptera, **214**, 220.
Isopyrum, 7.
Isotoma, 821.
Ispaghula, 1059.
Itea, 568.
Iteadaphne, 1155.
Itoa, 127.
Iva, 803.
Ivory, Pink, 410.
— Red, 410.
Ivy, Poison, 452.
Ixanthus, 939.
Ixonanthes, 273, **276**.
Ixora, 775, 776.

Jaborandi leaves, 314, 315.
Jaborosa, 977.

Jacaranda, 1011, 1013.
Jack Fruit, 1269.
Jackia, 775, 776.
Jacksonia, 533.
Jacobinia, 1023.
Jacquemontia, **956**, 964.
Jacquinia, **864, 866, 868,** 871.
Jagera, 430.
Jagua, 775.
Jak Tree, 1269.
Jalap, 964, 1067.
Jamaican Cogwood, 411.
Jambolana fruits, 629.
Jambosa, **626**, 630.
Jamesia, 577.
Janusia, 285.
Japanese lacquers, 460.
Japanese Persimmon, 886.
Japan wax, 460.
Jarrah, 630.
Jasione, **812**, 816.
Jasmine, 899.
Jasmine Root, Yellow, 932.
Jasminoideae, 899.
Jasminum, **888, 894,** 900.
Jasonia, 803.
Jateorhiza, 57.
Jatropha, 1234, 1235.
Jaundea, 476.
Jeffersonia, 63.
Jelutong, 916.
Jerdonia, 1002.
Jerusalem Artichoke, 799.
Joannesia, 1234, 1235.
Joannesieae, 1223, 1225.
Jodina, **1198**, 1201.
Jollydora, 476.
Juanulloa, 977, 978.
Juglandaceae, 459, 460, 465, 466, 1284–90.
Juglandales, 466.
Juglans, **1280, 1286,** 1290.
Juliania, 460, 466.
Julianiaceae, 460, 464–6, 1289.
Julianiales, 466.
Julocroton, **1211**, 1234.
Julostylis, 233.
Jurinea, 803.
Jussiaea, **662, 666,** 668.
Justicia, **1016**, 1023.
Jute fibres, 261.

Kadsura, **22**, 25.
Kadua, 776.
Kageneckia, 549.
Kajoe Lara wood, 630.
Kajoe Nani wood, 630.
Kalanchoë, 295, 581.
Kaldana, 964.
Kaliphora, 741.
Kallstroemia, 292.
Kalmia, **824, 828,** 836.
Kalopanax, **732**, 735.
Kamala, 1233.
Kamassi Boxwood, 916.
Kanahia, 924.
Kandelia, **606**, 611, 612.
Kapok, 241.
Karri, 630.
Karwinskia, 411, 413.
Katira Gum, 115.
Kaufmannia, 862.
Kava Root, 1127.
Kayea, **176**, 178, 179.
Kedrostis, 691.
Kei Apples, 127.
Keithia, 1052.
Kelleria, 1178.
Kelloggia, 775.
Kendrickia, 648.
Kennedya, 533.
Kentucky Coffee Tree, 500.
Keramanthus, 680.
Kernera, 87.
Kerria, **542**, 549.
Keruing, 220.
Khaya, 314, **334, 354,** 357, 358.
Kibara, 1144.
Kibatalia, 917.
Kibessia, 648.
Kickxia, 917.
Kielmeyera, 178.
Kielmeyeroideae, 171, 175, 177, 178, 195.
Kigelia, **1006**, 1011, 1013.
Kiggelaria, 127, 1230.
Kingiodendron, 501.
Kingwood, 461, 533.
Kino (in wood), 1136.
Kirilowia, **1076**, 1084.
Kirkia, **322**, 325.
Kirkieae, 320.
Kirkioideae, 324, 325.
Kissodendron, 735.
Kitaibelia, 233.
Kjellbergiodendron, 630.
Klainedoxa, 325.
Kleinhovia, 253.
Kleinia, 803.
Klugia, 1002.
Knautia, 781.
Kneiffia, 668.
Knema, **1132, 1134,** 1138.
Knightia, 1168.
Knoxia, 775.
Knysna Boxwood, 916.
Kochia, 1084.
Koeberlinia, 94, 324, 332.
Koeberliniaceae, 94, 324, 331–2.
Koelreuteria, 430, **438**.
Koenigia, 1100.
Kohlrabi, 87.
Kokia, 233.
Kokko, 486.
Kokoona, 397.
Kok-saghyz, 800.
Kola nuts, 253.
Kolkwitzia, 758.
Kolobopetalum, 57.
Koompassia, 501.
Koordersiodendron, 461.
Kopsia, 917.
Kopsiopsis, 991.
Kotchubaea, 776.
Krameria, 137, **536**, 538.
Krameriaceae, 137, 535–8.
Kribs's ray types, xliii.
Krigia, 803.
Krokia, 630.
Krugiodendron, 411, 413.
Krym-saghyz, 800.
Kumquat, Australian, **307**, 308.
Kunstleria, 534.
Kunzea, 630.
Kurrimia, **382, 392,** 397, 399.
Kydia, **228**, 233.

Labatia, **874**.
Labdanum, 102.
Labiatae, 639, 671, 1041–53.
Labichea, 501.
Lablab, 533.
Labordia, 932.
Labourdonnaisia, 879.
Labrador Tea, 835.
Labramia, 880.
Laburnum, **522**, 533, 534.
Laccodiscus, 430.
Lace-bark Tree, 1178.
Lachnaea, 1178.
Lachnastoma, 776.
Lachnopylis, **930**, 932.
Lachnostachys, 1040.
Lacistema, **1322**, 1322.
Lacistemaceae, 1320–2.
Lacmellia, 917.
Lacquers, Japanese, 460.
Lactoridaceae, 16, 38–9.
Lactuca, **784**, 803.
Lacunaria, **176**, 181.
Ladanum, 102.
Ladenbergia, 775, 776.
Laetia, 127.
Lafoensia, **652**, 654, **658**.
Lagenanthus, 939.
Lagenaria, 691.
Lagerstroemia, **652**, 654, **658**.
Lagetta, **1172**, 1178, 1181, **1186**.
Lagunaria, 233.
Laguncularia, **614**, 620.
Lallemantia, **1046**, 1052.
Lambertia, **1162**, 1168.
Lamellisepalum, 411.
Laminaria, 1101.
Lamium, **1044**, 1052.
Lamourouxia, 988.
Lampaya, 1040.
Lampranthus, 711.
Lancewood, 49, 775.
Landolphia, **904**, 917.
Lanessania, 1270.
Langsdorffia, 1207.
Lannea, **456**, 461.
Lansium, 358.
Lantana, **1034**, 1040, 1041.
Lanugia, 917.

Lapacho, 1011.
Lapachol (in wood), l, 1007.
Lapidaria, 711.
Laplacea, 190, 191.
Laportea, **1248**, **1250**, 1253.
Lappula, 954.
Lapsana, 803.
Lardizabala, 66.
Lardizabalaceae, 64–6, 67, 1137.
Larrea, **286**, **292**.
Laserpitium, 724.
Lasiadenia, 1178.
Lasiandra, 648.
Lasianthera, 376.
Lasianthus, 775, 776.
Lasiocorys, 1052.
Lasiocroton, 1235.
Lasiodiscus, 411, 413.
Lasiopetalum, 253.
Lasiophyton, 1178.
Lasiosiphon, **1172**, 1178.
Latex canals, 1349.
Latex, magnesium in, 1264.
Latex traces, 912, 1227.
Latex tubes, 475, 683, 912, 1219, 1227.
Lathraea, **980**, 991, **1006**.
Lathriogyna, 533.
Lathrophytum, 1207.
Lathyrus, **512**, 533.
Laticiferous cells, 1347.
Laticiferous elements, xiii.
Laticiferous system, xviii.
Latrobea, 533.
Lauan, 220.
Laugeria, 775.
Launea, 803.
Lauraceae, 111, 1137, 1139, 1143, 1144, 1145–56, 1156, 1157, 1159.
Laurales, 1137, 1156.
Lauranthoideae, 1189.
Laurelia, 1144, **1148**.
Laurel wood, Indian, 619.
Laurembergia, 599.
Laurentia, 821.
Lauridia, 397.
Laurocerasus, 549.
Lauroideae, 1153.
Laurus, **1148**, 1155.
Lautea, 741.
Lavandula, **1042**, 1052, 1053, **1058**.
Lavatera, 233.
Lavauxia, 668.
Lavender, 1051.
Lavigeria, 376.
Lavoisiera, 648.
Lavradia, 108, 338.
Lawia, 1104.
Lawsonia, 654, 954.
Layia, 803.
Leaf, annual increments of growth in, 351.
Leaf, epidermal cells horizontally divided, 1331.
Leaf, epidermal cells vertically divided, 1331.
Leaf, epidermis mucilaginous, 1330.
Leaf, epidermis papillose, 1330.
Leandra, 648.
Leatherwood, 571.
Leaves, ericoid, 8, 131, 145, 798, 827, 1169.
Lebeckia, 533.
Lebetanthus, 847.
Lecananthus, 775.
Lecaniodiscus, 430.
Lechea, 102.
Lechythopsis, 636.
Lecointea, 501.
Lecostemon, 553.
Lecythidaceae, 629, 631–6.
Lecythideae, 632.
Lecythis, 636.
Lecythopsis, 636.
Ledenbergia, 1091.
Ledum, 836.
Leea, **412**, **414**, **416**, 419.
Legnotideae, 610.
Leguminosae, 137, 291, 301, 424, 475, 476–535, 986, 1299.
Lehmanniella, 939.
Leichardtia, 57.
Leiphamos, 939.
Leitgebia, 338.
Leitneria, **1280**, 1283.
Leitneriaceae, 1282–3, 1289.
Lemaireocereus, **696**, 705.
Lemonwood, 775.
Lengths of wood cells, xxiii, xxvii, xlii.
Lennea, 534.
Lennoa, 851.
Lennoaceae, 850–1.
Lens, 533.
Lens cells, 709.
Lentibulariaceae, 586, 991–4.
Lenzia, 156.
Leonia, 108.
Leonotis, 1052.
Leontice, 63.
Leontodon, 803.
Leontopodium, 803.
Leonurus, 1052.
Lepidagathis, 1023.
Lepiderema, 430.
Lepidium, **84**, 87.
Lepidobotrys, 273.
Lepidoceras, 1194.
Lepidopetalum, 430.
Lepidophyllum, 803.
Lepiniopsis, 917.
Lepionurus, 381.
Lepisantheae, 421, 430.
Lepisanthes, 430.
Lepismium, 705.
Lepistemon, 964.
Leptactinia, 776.
Leptadenia, **910**, 924.
Leptandra, 987.
Leptaulus, **372**, 376.
Leptocereus, 705.
Leptochlaena, 223.
Leptocodon, 816.
Leptodermis, 775, 776.
Leptodesmia, 533.
Leptoglossis, 977.
Leptogonum, 1100.
Leptomeria, 1201.
Leptonychia, 253.
Leptospermoideae, 629, 630.
Leptospermum, 630.
Leptosyne, 803.
Lepuropetalon, 557.
Leretia, 376.
Leria, 803.
Leschenaultia, 809.
Lespedeza, 533, 534.
Lesquerella, 87.
Lessertia, 533.
Letterwood, 1269.
Lettuce, 799.
Leucadendron, **1166**.
Leucaena, 487.
Leucas, 1052.
Leucaster, 1067.
Leucastereae, 1061, 1063.
Leuchtenbergia, 705.
Leucocroton, 1235.
Leucodon, 775.
Leuconotis, 917.
Leucophyllum, 988.
Leucopogon, **838**, 847.
Leucosceptrum, 1053, **1058**.
Leucosmia, 1178.
Leucospermum, 1168.
Leucosyke, 1253.
Leucothoë, **828**, 836.
Levisticum, 724.
Lewisia, 156.
Leycesteria, **756**, 758.
Leyssera, 803.
Lhotzkya, 630.
Liatris, 803.
Libidibia, 501.
Licania, **552**, 553.
Licaria, **1150**, 1155.
Licopoli glands, 853.
Lightfootia, 816.
Lightia, 145.
Lignified cork, 1040.
Ligno-tubers, 827, 833.
Lignum Vitae, 291.
Ligusticum, **716**, 724.
Ligustrum, **888**, 900.
Lijndenia, 648.
Lilac, 899.
Liliaceae, 734, 924.
Lily of the Valley Tree, 839.
Lima Bean, 532.
Limacia, 57.
Limba, 619.
Limeum, 711.
Lime wood, 261.
Limnanthaceae, 298–9.
Limnanthemum, **934**, 939.

Limnanthes, 299.
Limnosipanea, 775.
Limonia, 316.
Limoniastrum, 857.
Limonium, **854**, 857.
Limosella, 988.
Linaceae, 137, 268–73, 275, 279, 284, 303, 1257.
Linaria, 988.
Linconia, 595.
Lindackeria, 127.
Lindelofia, 954.
Linden, 261.
Lindera, **1148**, 1155.
Lindernia, 988.
Lindheimera, 803.
Lindleya, 549.
Lingelsheimia, 1235.
Linnaea, 758.
Linociera, **894**, **898**, 900.
Linodendron, 1178.
Linostoma, 1178.
Linseed oil, 272.
Linum, **270**, 273, 1257.
Liparia, 533.
Liparophyllum, 939.
Lippia, **1034**, **1036**, 1040, 1041.
Liquidambar, **584**, **590**, 592.
Liquidambaroideae, 589.
Liquorice, 529, 531.
Liriodendrin, 19.
Liriodendron, **20**, 21, **32**.
Liriosma, **360**, 365, 366, 376.
Lisianthus, 939.
Lissanthe, 847.
Litchi, 430.
Litchis, 430.
Lithobium, 648.
Lithocarpus, **1312**, 1315.
Lithops, 711.
Lithospermeae, 949.
Lithospermum, **946**, 954.
Lithraea, **456**, 461.
Litsea, 1155.
Littorella, **1054**, 1059.
Llagunoa, 430.
Loasa, **658**, 669, **670**.
Loasaceae, 162, 668–9.
Lobelia, **818**, 821.
Lobeliaceae, 809, 816, 817–21.
Lobelias, arboreal, 819.
Lochnera, 917.
Locust Bean, 500.
Locust, Honey, 486.
Locust, West Indian, 500.
Loddigesia, 533.
Lodh Bark, 893.
Loeflingia, 152.
Loeselia, 942.
Loesenera, 501.
Logania, 932.
Loganiaceae, 772, 903, 925–33.
Loganioideae, 925, 926, 928, 931.
Logwood, 500.
Loiseleuria, 836.
Lomatia, **1164**, 1168.
Lonas, 803.
Lonchocarpus, **472**, **504**, 533, 534.
Lonchostoma, 595, **598**.
Longetia, 1235.
Lonicera, **756**, 758.
Loofahs, 691.
Lopezia, 668.
Lophanthera, 285.
Lophanthus, 1052.
'*Lophicarpus*', 1091.
Lophiocarpus, 1084.
Lophira, 219, **330**, 338.
Lophogyne, 1104.
Lophopetalum, **392**, 397, 399.
Lophophytum, 1207.
Lophopterys, **280**, 285.
Lophospermum, 988.
Lophostachys, 1023.
Lophostoma, 1178.
Loquat, 548.
Loranthaceae, 1188–94, 1204, 1206.
Loranthoideae, 1189.
Loranthus, **1180**, **1190**, **1192**, 1194.
Loreya, 648.
Loropetalum, 592.
Loteae, 503, 507, 508, 510.
Lotononis, 533.
Lotus, 533.
Loudonia, 599.
Lourea, 533.
Lovoa, **354**, 358.
Lovoinoideae, 355, 356.
Loxodiscus, 430.
Loxonia, 1002.
Loxopterygium, 461.
Loxostylis, 461.
Lubinia, 862.
Lucerne, 532.
Lucilia, 803.
Luculia, **764**, 775, 776.
Lucuma, **874**, **878**, 880.
Ludia, 127.
Ludwigia, 668.
Luehea, 262.
Lueheopsis, **256**, 262.
Luffa, 691.
Lumnitzera, **616**, 620.
Lunania, 127.
Lunaria, **84**, 87.
Lundia, 1011.
Lupin, 532.
Lupinus, 533, 534.
Luxemburgia, 338.
Luzula, 722.
Lychnis, 152, **160**.
Lychnodiscus, 430.
Lychnophora, 803.
Lycianthes, 978.
Lycium, **966**, **968**, **970**, 977, 978.
Lycopersicum, 977.
Lycopsis, 954.
Lycopus, **1044**, 1052.
Lycoseris, 803.
Lygodisodea, 775.
Lyonia, **826**, **828**, 836.
Lyonothamnus, 549.
Lyonsia, 917.
Lyperia, 988.
Lysiloma, 487.
Lysimachia, **842**, **860**, 862.
Lysinema, 847.
Lysiosepalum, 253.
Lysiostyles, 964.
Lythraceae, 609, 649–55, 656, 657, 660, 663, 664, 954.
Lythrum, 654.

Maba, 886.
Mabea, 1234, 1235.
Macadamia, **1164**, 1168.
Macairea, 648.
Macaranga, **1224**, 1234, 1235.
Macarisia, 611, 612.
Macarisieae, 602, 610, 611.
Macarthuria, 711.
Mace, 1138.
Maceration methods for wood, liv.
Macfadyena, 1011.
Macgregoria, 404.
Machaerium, 533, 534.
Machaonia, 775, 776.
Machilus, **1150**, 1155.
Mackinlaya, 735.
Macleania, 827.
Macleaya, 78.
Maclura, **1248**, **1266**, 1270.
Macoubea, 917.
Macphersonia, 430.
Macqui, 266.
Macrocarpium, 741.
Macrocentrum, 648.
Macrocnemum, 775, 776.
Macrococculus, 57.
Macrodiscus, 1013.
Macrolobium, 501.
Macropanax, 735.
Macropteranthes, 620.
Macrostylis, 316.
Macrotomia, 954.
Macrua, 94, 95.
Madar Fibre, 923.
Madhuca, **874**, **878**, 879, 880.
Madia, 803.
Maesa, **868**, 871.
Maesobotrya, 1235.
Maesopsis, **408**, 411, 413.
Magnesium in latex, 1264.
Magnolia, 21, **32**.
Magnoliaceae, 6, 15, 16, 16–21, 21, 25, 26, 37, 38, 39, 42, 43, 45, 49, 51, 111, 1137, 1143.
Magnoliales, 16, 25, 31, 38, 39, 568, 591.
Magonia, 430.
Magydaris, 724.

Mahafalia, 924.
Mahogany, 357.
— African, 257.
— Burma, 261.
— Colombian, 636.
— Gaboon, 142, 349.
— Rose, 357.
— Sapele, 357.
Mahonia, **58**, 63.
Mahurea, 178, 179.
Maieta, 648.
Maillardia, 1270.
Maingaya, 592.
Makoré, 879.
Malacantha, 880.
Malachra, **224**, 233.
Malacocarpus, 705.
Malaisia, 1270.
Malanea, **760**, 775.
Malesherbia, 684.
Malesherbiaceae, 163, 683–4.
Malic acid, 709.
Mallet Bark, 629.
Mallotus, **1224**, 1234, 1235.
Mallows, 233.
Malmea, 49.
Malope, 233.
Malosma, 461.
Malouetia, 917.
Malpighia, **280**, 285.
Malpighiaceae, 137, 142, 145, 279–85, 361.
Malus, 549.
Malva, 233, **244**.
Malvaceae, 223, 223–34, 235, 236, 240, 241, 242, 243, 245, 252, 253, 254, 257, 260, 1229.
Malvales, 212, 219, 267.
Malvastrum, **224**, 233.
Malvaviscus, **228**, 233, 253.
Malveae, 225, 229, 230, 232.
Mammea, **176**, 178, 179.
Manaca-root, 977.
Manbarklak, 636.
Mandarin, Szinkum, 308.
Mandevilla, 917.
Mandragora, 977.
Mandrake, English, 691.
Manettia, **764**, 775.
Mangifera, **450**, **456**, 459, 461.
Mangiferae, 459.
Manglietia, **20**, 21.
Mango, 460.
Mangolds, 1083.
Manihot, 1234, 1235.
Manihoteae, 1225.
Manilkara, 880.
Manna, 899.
Manna Ash, 899.
Manna, Tamarix, 158.
Mannia, 325.
Manniophyton, 1234.
Manotes, **470**, 476.
Mansonia, 253.
Mansonia, **250**, 253.
Mansonieae, 252.
Manwood, Black, 366.
Maoutia, 1253.
Maple, Bird's-eye, 435.
— Hard, 435.
— Rock, 435.
— Soft, 435.
Mapouria, 775, 776.
Mappia, 376.
Mappianthus, 376.
Maprounea, 1234, 1235.
Maranta, 963.
Marantaceae, 963.
Marathrum, 1104.
Marblewood, Andaman, 886.
Marcgravia, **192**, **202**, 203, 340.
Marcgraviaceae, 199–203, 204, 205, 340.
Mareya, **1226**, 1234, 1235.
Marianthus, 131.
Maria, Palo, 178.
Maria, Santa, 178.
Marigold, 802.
Marila, 178, 179.
Marina, 533.
Maripa, **956**, 964.
Marjoram, 102, 1051.
Markea, 977.
Markhamia, **1008**, 1013.
Marlea, **750**.
Marlierea, 630.
Marlothia, 411.
Marmalade Plum, 879.
Marquesia, 220.
Marrubium, **1046**, 1052.
Marsdenia, **920**, 924.
Marsypianthus, 1052.
Martinella, 1013.
Martiodendron, 501.
Martynia, 1014, **1026**.
Marupá, 325.
Mascagnia, **280**, 285.
Mascarenhasia, 917.
Massandaruba, 879.
Mastic, 460.
Mastichodendron, 880.
Mastixia, **738**, 741.
Matayba, 430.
Maté, 385.
Maté Tea, 376, 385, 774, 871, 893.
Maté Tea, substitute for, 376.
Mathurina, 674.
Matisia, **240**, 241.
Matisieae, 235, 241.
Matricaria, 803.
Matthaea, 1144.
Matthiola, **80**, 87.
Maurandia, 988.
Mauria, 461.
Maurocenia, 397.
Maxwellia, 241.
Mayepea, 900.
Mayna, 127.
Mayodendron, 1013.
Maytenus, 397.
Mazus, 988.
Measurement of cell length, lv.
Meconella, 78.
Meconopsis, 78.
Mecopus, 533.
Mecranium, 648.
Medicago, 533, 534.
Medicosma, 316.
Medinilla, **638**, **640**, 648.
Medinillopsis, 648.
Medullary bundles, xxi, 1342.
Medullary cork, 310, 810, 813, 1057.
Medullary phloem, 1343.
Medullary rays, broad, 1340.
Medullary rays, narrow, 1341.
Medullary rays, narrow and broad, 1341.
Medullated protostele, xxxi, xxxiv.
Medusagynaceae, 203–4.
Medusagyne, 204.
Medusanthera, 376.
Megalodonta, 803.
Megaphyllaea, 357.
Megaphytic habit, 791.
Megapterium, 668.
Meiogyne, 49.
Melaleuca, 630.
Melampyrum, 988.
Melananthus, **966**, 977.
Melandrium, 152.
Melanochyla, 461.
Melanodiscus, 430.
Melanolepis, 1235.
Melanophylla, 741.
Melanorrhoea, **456**, 461.
Melanoxylon, 501.
Melasma, 988.
Melastoma, **638**, 648.
Melastomaceae, 637–49.
Melastomoideae, 637, 645, 646, 647.
Melhania, 253.
Melia, 357, 358.
Meliaceae, 314, 347, 348, 349–58, 429.
Melianthaceae, 441–3.
Melianthus, **438**, 443.
Melichrus, 847.
Melicocca, 430.
Melicope, 316.
Melicytus, **100**, 108.
Melientha, 381.
Melilotus, 533.
Melioideae, 357.
Meliosma, **444**, **450**, 452.
Meliosmaceae, 451.
Melissa, 1052.
Melittis, 1052.
Melloa, 1011, 1013.
Melochia, 253.
Melodinus, 917.
Melons, 691.
Melothria, 691.

Memecyleae, 637, 639, 645, 647.
Memecylon, **638**, 648.
Memora, 1013.
Menabea, 924.
Mendoncia, **1010**, 1023.
Menendezia, 648.
Meni Oil, 338.
Menispermaceae, 52–8, 62, 66, 641, 1137.
Menispermum, **54**, 57.
Menodora, 900.
Mentha, 1052.
Mentzelia, 669.
Menyanthes, **934**, 939.
Menyanthoideae, 933, 936, 938.
Menziesia, 836.
Meranti, 220.
Meranti Damar Hitam, 219.
Meranti Pa'ang, 218.
Meranti, Red, 220.
Meranti, substitute for, 656.
Merciera, 816.
Mercurialis, **1216**, 1234, 1235.
Meriandra, 1052.
Meriania, **646**, 648.
Mericarpaea, 775.
Merremia, 964.
Merrillia, 316.
Merrilliodendron, 376.
Mertensia, **950**, 954.
Meryta, 735.
Mesembryanthemum, 711.
Mesogyne, 1270.
Mesophyll cells, reticulate thickenings in, 26–7, 641.
Mesophyll, centric, 1333.
Mesophyll, fibres in, 45, 117, 143, 157, 180, 205, 279, 287, 369, 375, 420, 421, 476, 480, 491, 588, 612, 613, 621, 632, 865, 873, 891, 907, 919, 948, 957, 1032, 1133, 1139, 1170, 1176, 1181, 1182.
Mesophyll, homogeneous, 1334.
Mesophyll, isobilateral, 1334.
Mesophyll, sclereids in, 29, 36, 222, 491, 641, 753, 855.
Mesophyll, sclerosed cells in, 133, 171, 399, 400, 405, 421, 439, 453, 473, 509, 535, 595, 641, 880, 881, 907, 1129, 1162.
Mesophyll, stellate cells in, 149, 1146.
Mesophyll, stone cells in, 205, 473, 491, 621, 694, 927, 1146, 1188, 1189, 1205.
Mesophyll, tracheae in, 269.
Mesophyll, tracheids in, 140, 157, 171, 641, 1039, 1195.
Mespilodaphne, 1155.
Mespilus, 549.
Mesua, **176**, 178, 179.
Metalasia, 803.
Metatracheal parenchyma (in wood), xxiv.
Metopium, 461.
Metrodorea, 316.
Metrosideros, 630.
Mettenius glands, 853.
Metternichia, 977.
Meum, **714**, 724.
Meumathamanticum, **714**.
Meyenia, 1023.
Mezereum, 1177.
Mezia, 285.
Meziella, 599.
Mezoneurum, 501.
Mezzettia, 49.
Michauxia, 816.
Michelia, **20**, 21, **32**.
Miconia, 648.
Micrandra, 1234.
Micrantheum, 1234.
Micrechites, 917.
Microcala, 939.
Microchemistry, xvii.
Microcitrus, 316.
Microcodon, 816.
Microcos, 262.
Microdesmis, 1234, 1235.
Microlepis, 648.
Microlicia, 648.
Micromeles, 549.
Micromelum, 316.
Micromeria, 1052.
Micronychia, 461.
Microphysa, 648.
Microplumeria, 917.
Micropus, 803.
Microrhamnus, 411, 413.
Microsemma, 1178, 1181, **1186**.
Microsteira, 285.
Microstemon, **456**, 461.
Microtea, 1091.
Microtropis, 397.
Miersiophyton, 57.
Mignonette, 97.
Mikania, **784**, 804.
Mildbraediodendron, 501.
Miliusa, 49.
Milkweed, American, 924.
Millettia, **520**, **522**, 533, 534.
Millingtonia, 1013.
Mimetes, 1168.
Mimosa, **478**, 487.
Mimosaceae, 476–87, 488, 489, 492, 521, 524, 527, 528, 529.
Mimosoideae, 519.
Mimulus, **982**, 988.
Mimusops, **874**, **878**, 880.
Minquartia, 366.
Mint, 1051.
Mint, adulterant in, 325.
Minuartia, 152.
Miquelia, 376, **382**.
Mirabilis, **1062**, 1067.
Miraculous Berry, 879.
Mirbelia, 533.
Miré, 977.
Misanteca, 1155.
Mischocarpus, 430.
Mischodon, **1226**, 1235.
Mitchella, 775.
Mitella, 557.
Mitostemma, 680.
Mitracarpum, 775.
Mitragyna, **768**, 776.
Mitrasacme, 932.
Mitreola, 932.
Mitrephora, **46**, 49.
Mitriostigma, **764**, 775.
Mniopsis, 1104.
Moldenhawera, 501.
Molinaea, 430.
Mollia, 262.
Mollinedia, 1144.
Mollugo, 711.
Molopanthera, 775.
Moltkia, 954.
Momordica, **686**, 691, 694.
Monarda, **1046**, 1052, 1053.
Moneses, 836.
Monimia, 1144.
Monimiaceae, 15, 111, 1137, 1138–45, 1153, 1156, 1159, 1252.
Monimioideae, 1142, 1143.
Monkey Pots, 636.
Monnieria, 316.
Monnina, 138.
Monochaetum, 648.
Monochilus, 1040.
Monococcus, 1091.
Monocosmia, 156.
Monocotyledons, 5, 62, 67, 68, 70, 78, 690, 988, 1120, 1123, 1126, 1194.
Monocotyledons, phylogeny of, lii.
— systematic anatomy of, lii.
Monodora, 49, **54**.
Monolena, 648.
Monolepis, 1084.
Monophyllaea, 1002.
Monoporandra, 220.
Monopteryx, 534.
Monotes, **216**, 220.
Monotoca, **838**, 847.
Monotoideae, 212.
Monotropa, 834, 835, 840.
Monotropaceae, 834, 839–40.
Monotropastrum, 840.
Monotropsis, 840.
Monsonia, 297.
Montezuma, **240**, 241.
Montia, 156, **160**.
Montioideae, 153.
Montrouziera, 178, 179.
Monttea, 988.
Moquilea, 553.
Moquinia, 803, 804.
Mora, 501.
Moraceae, 1252, 1257, 1259–71, 1277, 1289.

Moreae, 1269.
Morelia, 776.
Moricandia, 87.
Morierina, 776.
Morina, 781.
Morinda, 775, 776.
Moringa, 441, **470**, 471.
Moringaceae, 468–71.
Morisonia, 94, 95.
Moroideae, 1229, 1269.
Moronobea, 178, 179.
Moronoboideae, 171, 177, 178.
Morrenia, 924.
Mortonia, 397.
Mortoniodendron, 262.
Morus, **1248**, **1264**, 1270.
'*Moschoxylum*', 358.
Mosquitoxylum, 461.
Mostuea, 932.
Motherwellia, 735.
Mourera, 1104.
Mouriria, **622**, **646**, 648.
Moutabea, **130**, 138, 139.
Moutabeae, 133.
Mucilage canals, 1349.
Mucilage cavities, 1348.
Mucilage cells, 1347, 1354.
Mucilaginous leaf epidermis, 1330.
Mucor, 991.
Mucuna, 533, 534.
Muehlenbeckia, 1100, 1101.
Muellera, 533, 534.
Mulberry, Black, 1269.
— Paper, 1270.
Mulgedium, 803.
Mulinum, 724.
Multinucleate fibres, 974.
Mummy Pea, 532.
Mundtia, 138.
Mundulea, 533.
Mungongo, 1233.
Muntingia, 266.
Muraltia, 138.
Muretia, 724.
Murraya, 316.
Musanga, 1229, 1270.
Musgravea, 1169.
Mussaenda, 775, 776.
Mussaendopsis, **766**, 775, 776.
Musschia, 816.
Mustard, 86, 903.
Mutisia, 803.
Mutisieae, 783.
Mycorrhiza, 62, 791, 797, 819, 822, 823, 827, 833, 839, 849, 850, 913, 922, 933, 936, 1057, 1118, 1126, 1187, 1314.
Myginda, **392**, 397.
Myodocarpus, 735.
Myonima, 775.
Myoporaceae, 953, 1024–7.
Myoporum, **1020**, **1026**, 1027, **1054**.
Myoschilos, **1198**, 1201.
Myosotis, 954.
Myosurus, 7.
Myrceugenia, 630.
Myrcia, 630.
Myrianthus, 1270.
Myrica, **1280**, **1286**, 1294.
Myricaceae, 1289, 1291–4.
Myricaria, 159.
Myriocarpa, 1229, **1250**, 1253.
Myrioneuron, 775.
Myriophyllin, 1325.
Myriophyllum, 599, **600**, 601.
Myristica, **1132**, 1138.
Myristicaceae, 57, 110, 111, 1132–8, 1143, 1152, 1153, 1159.
Myristiceae, 1159.
Myrmecodia, 775.
Myrmidone, 648.
Myrobalans, 619.
Myrocarpus, 534.
Myrosin cells, xviii, 1347.
Myrospermum, 533, 534.
Myrothamnaceae, 593–4, 1281.
Myrothamnus, 594.
Myroxylon, **512**, 533, 534.
Myrrh, 348.
Myrrhinium, 630.
Myrrhis, 724.
Myrsinaceae, 463, 765, 863–71.
Myrsine, **866**, 871.
Myrtaceae, 125, 620–31, 631, 635, 648, 651.
Myrteae, 629.
Myrtekmania, 630.
Myrtella, 630.
Myrtus, **626**, 630.
Mystrin, 1205, 1206.
Mystropetalon, 1207.
Mystroxylon, 397.
Mytilaria, 592.
Myzodendraceae, 1203–5.
Myzodendron, **1204**, 1205.

Nabiasodendron, 190.
Naio, 1027.
Nama, 945.
Nananthus, 711.
Nandina, 63.
Napaea, 233.
Napeanthus, 1002.
Napeodendron, 430.
Napoleona, **634**, 636, **638**.
Napoleoneae, 632.
Naravelia, 7.
Narra, 533.
Nassauvia, 803.
Nasturtium, 305.
Nasturtium, 87.
Natsiatum, 376.
Nauclea, 775, 776.
Naucleopsis, **1266**, 1270.
Nealchornea, 1235.
Nebelia, 595.
Necepsia, 1235.
Nectandra, 1155.
Nectaries, extra-floral, 139, 140, 196, 200, 213, 225, 236, 243, 297, 317, 318, 506, 539, 540, 685, 701, 752, 753, 822, 881, 894, 895, 926, 980, 1030, 1031, 1093, 1094, 1208, 1209.
Nectaropetalum, 277.
Neea, **1058**, **1062**, 1067, 1073.
Needhamia, 847.
Needle Wood, 190.
Neesia, 241.
Neillia, 549.
Nelsonia, 1023.
Nelumbium, **68**, 71.
Nemacaulis, 1100.
Nematanthus, 1002.
Nematolepis, 316.
Nematostylis, 775.
Nemesia, 988.
Nemopanthus, 385.
Nemophila, 945.
Nenax, 775.
Neoabbottia, 705.
Neoboutonia, 1235.
Neocouma, 917.
Neolitsea, 1155.
Neomammillaria, 705.
Neomezia, 871.
Neomillspaughia, 1101.
Neonauclea, 776.
Neoschroetera, 292.
Neoscortechinia, **1226**, 1235.
Neosparton, 1040.
Nepenthaceae, 1105–11.
Nepenthes, 557, 560, **1106**, **1108**, **1110**, 1111.
Nepeta, 1052.
Nephelium, 430.
Nephrophyllidium, 939.
Nepsera, 648.
Neptunia, 487.
Nerium, 917.
Nertera, 775.
Nesaea, 654.
Nesogordonia, 262.
Neumannia, 127.
Neuracanthus, 1023.
Neurada, 549.
Neuropeltis, 964.
Neurotheca, 939.
Neviusa, 549.
New Caledonian Sandalwood, 1201.
Niangon, 253.
Nicandra, **968**, 977.
Nicodemia, **920**, 932.
Nicotiana, 978.
Niebuhria, 95.
Niederleinia, 147.
Niemeyera, 880.
Nierembergia, 978.
Nigella, **2**, 7.
Nissolia, 533.
Nitraria, **292**.

Nitrophila, 1084.
Nivenia, 1168.
Noaea, 1084.
Nodal anatomy, xxxviii, xxxix, 19, 24, 26, 37, 41, 43, 50, 370, 375, 518, 554, 555, 830, 843, 847; 1219.
Nodules, bacterial, 291, 1304–5.
Nodules, bacterial, on leaves, 760, 763.
Nodules, root, 410, 503, 527, 827, 833, 986, 1187, 1291, 1293, 1299, 1304.
Noisettia, 108.
Nolana, **958**, 964.
Nolaneae, 955, 961, 963.
Noltea, 411.
Nonnea, 954.
Nopalea, 705.
Norantea, **202**, 203, 340.
Noronhia, 900.
Norrisia, **930**, 932.
Northiopsis, 880.
Nostoc, in tissues of *Gunnera*, 596, 597.
Notelaea, 900.
Nothaphoebe, 1155.
Nothapodytes, 376.
Nothocestrum, 978.
Nothofagus, **1306**, **1312**, 1315.
Nothopanax, 735.
Nothopegia, 461.
Notobuxus, 1241.
Notopleura, 776.
Notothixos, 1194.
Notothlaspi, 87.
Nototrichium, 1074.
Nouettea, 917.
Noyera, 1270.
Nuclear crystalloids, 1005.
Nuclei, giant, 689, 1206.
Nuphar, 71, **72**.
Nut, Brazil, 636.
— Coula, 366.
— Gaboon, 366.
— West African Dika, 325.
Nutmegs, 1137.
Nutmegs, Peruvian, 1144.
Nuts, Butter, 199.
— Cashew, 460.
— Coula, 366.
— Filbert, 1309.
— Kola, 253.
— Pistachio, 460.
— Sapucaia, 636.
— Turkey, 1309.
Nuttallia, 549.
Nuxia, 932.
Nux-vomica, 932.
Nuytsia, 1194.
Nyctaginaceae, 1059–67, 1073.
Nyctanthes, 900.
Nycticalanthus, 316.
Nymphaea, **68**, 71.
Nymphaeaceae, 67–71, 937.
Nyssa, **742**, **746**, **750**, 752.
Nyssaceae, 740, 748–52.

Oak, Black, 1314, 1315.
— Red, 1314, 1315.
— Silky, 871.
— Tasmanian, 630.
— Tulip, 253.
— White, 1314, 1315.
Obeche, 253.
Obetia, **1250**, 1253.
Obione, **1080**, 1084.
Obolaria, 939.
Ochanostachys, **360**, 366.
Ochna, **330**, 338.
Ochnaceae, 104, 108, 204, 219, 267, 268, 333–8, 340.
Ochradenus, 97.
Ochrea, 1093.
Ochroma, **238**, 241.
Ochrosia, 917.
Ochthocharis, 648.
Ochthocosmus, 273, **276**.
Ocimum, 1052.
Ocotea, **1150**, 1155.
Octodon, 775.
Octoknema, 366, **372**, 379.
Octoknemaceae, 366, 377–9.
Octolepis, 1178.
Octolobus, 253.
Octomeles, **696**, 698.
Odina, **456**, 461.
Odontadenia, 917.
Odontites, 988.
Odontophorus, 711.
Odontospermum, 803.
Odyendea, **322**, 325.
Oecopetalum, 376.
Oedematopus, **172**, 178.
Oenanthe, **714**, 724.
Oenone, 1104.
Oenothera, **658**, **662**, 668.
Oftia, 1027.
Ogcodeia, 1270.
Ohio Buckeye, 441.
Oil, 723.
Oil cells, 1347, 1354.
Okoubaka, 366, 379.
Okoumé, 349.
Olacaceae, 362–7, 375, 378, 379, 381, 1200.
Olacales, 381.
Olaceae, 375.
Olacineae, 268, 365, 375, 380.
Olacoideae, 366.
Olax, **360**, 366.
Oldenlandia, 775.
Oldfieldia, **1226**, 1235.
Olea, **894**, **898**, 900.
Oleaceae, 213, 893–900.
Olearia, **784**, 803, 804.
Oleoideae, 899.
Oliganthes, 803, 804.
Oligarrhena, 847.
Oligomeris, 97.
Olinia, **652**, 657.
Oliniaceae, 656–7.
Olisbea, 648.
Olive, 899, 900.
Olive Oil, 899.
— a substitute for, 879.
Olive, wild, 366.
Olive wood, 900.
Olmedia, 1270.
Olmediella, 127.
Olmedioperebea, 1270.
Olmediophaena, 1270.
Olneya, 533.
Omphacomeria, 1201.
Omphalea, 1234, 1235.
Omphalocarpum, 880.
Omphalodes, 954.
Omphalopus, 648.
Onagraceae, 664–8.
Oncinotis, **906**, 917.
Oncoba, **118**, 127.
Oncobeae, 117.
Oncocarpus, 461.
Oncotheca, 886.
Ongokea, **360**, 366.
Onobrychis, 533.
Ononis, 533.
Onopordon, 803.
Onoseris, 803.
Onosma, 954.
Oocarpon, 668.
Opepe, 774.
Operculina, 964.
Ophiobotrys, 127.
Ophiocaryon, 452.
Ophiorrhiza, 775.
Opilia, 381.
Opiliaceae, 379–81.
Opilieae, 380.
Opisthocentra, 648.
Opium, 78.
Opopanax, 724.
Opposite intervascular pitting, *see* 'Vessels'.
Opuntia, **700**; 705.
Orange, Osage, 1269, 1270.
Orange, Washington Navel, 314.
Oregandra, 776.
Oreodaphne, 1155.
Oreopanax, 735.
Oreopolus, 775.
Oricia, 316.
Origanum, 102, 1052.
Origin of herbs and trees, xxxii.
Orites, **1166**, 1169.
Orixa, 316.
Ormocarpum, 533.
Ormosia, 533, 534.
Ornithopus, 533.
Orobanchaceae, 985, 986, 988–91.
Orobanche, 991, **1006**.
Orophea, 49.
Oroxylon, 1011, 1013.
Orphium, 939.

Ortegia, 152.
Orthocarpus, 988.
Orthopterygium, 466.
Orthosiphon, 1052.
Orygia, 711.
Osage Orange, 1269, 1270.
Osbeckia, 648.
Osbeckieae, 639, 644.
Osbornia, 630.
Osmanthus, 900.
Osmelia, 127.
Ossaea, 648.
Osteomeles, 549.
Osteospermum, 803.
Ostodes, 1234, 1235.
Ostrearia, 592.
Ostrowskia, 816.
Ostrya, 1289, **1300**, **1302**, 1305, 1309.
Ostryocarpus, 534.
Ostryopsis, 1305, 1309.
Osyridocarpus, 1201.
Osyris, **1192**, 1201.
Otanthera, 648.
Otherodendron, 397.
Otiophora, 775.
Otomeria, 775.
Otonephelium, 430.
Otophora, 430.
Ottoschulzia, 376.
Oubanguia, 268.
Oudneya, 87.
Ougeinia, 533, 534.
Ouratea, **330**, 338.
Ourisia, **982**, 988.
Ovidia, 1178.
Owenia, 358.
Oxalic acid, 709.
Oxalidaceae, 295, 299–303.
Oxalis, **296**, 303.
Oxandra, **48**, 49.
Oxera, **1034**, 1040.
Oxyanthus, 776.
Oxydendrum, **826**, 836.
Oxygonum, 1100.
Oxylobium, 533.
Oxymeris, 648.
Oxymitra, 49.
Oxyspora, 648.
Oxystigma, 501.
Oxytheca, 1100.
Oxytropis, 533.

Pachira, 241.
Pachyanthus, 648.
Pachycentria, 648.
Pachygone, 57.
Pachylobus, **346**, 349.
Pachyloma, 648.
Pachynema, 11.
Pachypodanthium, 49.
Pachypodium, 917.
Pachyrhizus, 533, 534.
Pachysandra, **1238**, 1241.
Pachystachys, 1023.
Pachystela, **874**.
Pachystima, 397.
Pachystroma, 1234, 1235.
Pachytrophe, 1270.
Pacourina, 803.
Padauk, 533.
Padus, 549.
Paederia, 775, 776.
Paederota, 988.
Paeonia, 7, 49.
Pagamea, 775.
Pagetia, 316.
Pagiantha, 917.
Pahudia, 501.
Pajanelia, 1013.
Palaquium, **874**, 880.
Palava, 233.
Palicourea, 775, 776.
Palisade ratio, 975.
Paliurus, 411, **412**, 413.
Pallenis, 803.
Palmeria, 1144.
Palo Blanco, 775.
Palo Maria, 178.
Pamphilia, 890.
Panax, **728**, **732**, 735.
Pancheria, 564.
Pancovia, 430.
Panderia, 1084.
Pandorea, 1011.
Pangium, 127.
Paniband, 974.
Panopsis, 1169.
Papain, 683.
Papaver, **76**, 78.
Papaveraceae, 74–8, 78, 79, 87.
Paper Mulberry, 1270.
Paphia, **826**, 827.
Papilionaceae, 476, 483, 486, 487, 488, 489, 491, 500, 502–35.
Papilionatae, 527, 529.
Papillose leaf epidermis, 1330.
Pappea, 430.
Parabaena, 57.
Parabarium, 917.
Parabignonia, 1011.
Paracaryum, **950**, 954.
Paracytic stomata, xv.
Paradrypetes, 1235.
Paragonia, 1011.
Paraguay Tea, 385.
Parahancornia, 917.
Paralstonia, 917.
Paramachaerium, 534.
Paramignya, 316.
Paranephelium, 430.
Pararistolochia, 1119.
Parartocarpus, 1270.
Para Rubber, 800, 1231.
— Tree, 1270.
Parashorea, 220.
Parasponia, 1278.
Parastemon, 553.
Paratecoma, 1013.
Parathesis, 871.
Paratrophis, 1270.
Parenchyma (in wood):
— abaxial, xxv, 135, 143, 175, 217, 271, 275, 278, 289, 337, 373, 398, 446, 496, 521, 563, 607, 627, 833.
— absent or rare, 61, 65, 101, 107, 122, 132, 168, 175, 311, 378, 393, 440, 451, 573, 577, 633, 659, 739, 769, 813, 832, 971, 984, 1037, 1221.
— aliform, xxiv, xlvi, l.
— apotracheal, xxiii, l.
— banded, xxiv.
— confluent, xxiv, xlvi, l.
— diffuse, xxiv, xlv, xlviii.
— diffuse - in - aggregates, xxiv.
— fusiform cells, xxv, xlvi, 77, 93, 158, 229, 230, 238, 248, 249, 289, 311, 329, 361, 364, 380, 427, 433, 440, 443, 463–7, 469, 484, 496, 523, 645, 794, 869, 897, 902, 921, 929, 944, 951, 985, 1007, 1065, 1066, 1072, 1082, 1159, 1174, 1193, 1251, 1275.
— inflated cells, 496.
— initial, xxiv.
— metatracheal, xxiv.
— paratracheal, xxiii, xlvi, xlviii, l.
— pith-like, 258.
— reticulate, xxiv, 47, 122, 364, 673, 892, 944.
— scanty paratracheal, xxiv.
— sclerotic, 271, 311, 496, 523, 911, 1007, 1225.
— septate, 168, 180, 345, 373, 496, 929.
— spongy tissue, 469.
— storied, 1352.
— strands, xxv, xlvi.
— terminal, xxiii.
— unilaterally paratracheal, 175, 177, 1174, 1179.
— unlignified, 417, 524, 657, 1251.
— vasicentric, xxiv.
Pareira brava, 57.
Parietaria, **1248**, 1253.
Parietarieae, 1247, 1249.
Parinari, **552**, 553.
Parishia, **456**, 461.
Paritium, 233.
Parkia, 487.
Parkieae, 479.
Parkinsonia, 501.
Parmentiera, **1008**, 1011, 1013.
Parnassia, 557, 777.
Parnassiaceae, 557.
Parochetus, 533.
Paronychia, 152.
Paropsia, 680.
Paropsieae, 126.

Paropsiopsis, 680.
Parosela, 534.
Parrotia, 592.
Parrotiopsis, 592.
Parsley, 723.
Parsnip, 723.
Parsonsia, 917.
Parthenium, 803.
Parthenocissus, **416**, 419.
Partridge Wood, 533.
Paschanthus, 680.
Passerina, **1172**, 1178.
Passiflora, **672**, 680, **682**.
Passifloraceae, 126, 673, 674–80, 681.
Passion Flowers, 680.
Patagonula, 954.
Patchouli, 1051.
Patrinia, 779.
Patrisia, 127.
Pau Hoi, 1155.
Paullinia, 430, **438**.
Paulownia, **982**, 988, **1000**.
Pau Marfim, 314.
Pau Mulatto, 775.
Pauridiantha, 775.
Pausandra, 1234, 1235.
Pausinystalia, 776.
Pavetta, **764**, 775, 776.
Pavonia, 233.
Pawpaw, 683
Paxia, 476.
Payena, 880.
Paypayrola, 108.
Peach, 548.
Pea, Mummy, 532.
Pear, 548.
Pear, Anchovy, 636.
— Avocado, 1153.
— Hard, 657.
— Prickly, 705.
— Wild, 475.
Pear wood, 549.
Pecan, 1290.
Pectis, 803.
Pedaliaceae, 1013–14.
Pedalium, 1014.
Peddiea, 1178.
Pedicularis, **980**, 988.
Pedilanthus, 1234, 1235.
Peganum, 292, 316.
Peglera, 275.
Pegolettia, 803.
Pegwood, 757.
Peiranisia, 501.
Peixotoa, **280**, 285.
Pelagodendron, 776.
Pelargonium, **296**, 297.
Pelea, 316.
Pelecyphora, 705.
Pellacalyx, **608**, 612.
Pelliciera, 189, 205.
Pellicieraceae, 204–5.
Pellitory, 802.
Peltanthera, 932.
Peltaria, 87.
Peltiphyllum, 557.
Peltogyne, 501.
Peltophorum, 501.
Pemphis, **652**, 654.
Penaea, **1182**, 1183.
Penaeaceae, 1181–3, 1183, 1188.
Peniocereus, 705.
Pennantia, **372**, 376.
Pentace, **256**, 262.
Pentachondra, 847.
Pentaclethra, 487.
Pentacme, **218**, 220.
Pentadesma, 178, 179.
Pentagonia, 775, 776.
Pentanisia, 775.
Pentapanax, 735.
Pentaphalangium, 179.
Pentaphragma, 816.
Pentaphragmataceae, 814, 816.
Pentaphylacaceae, 206–7.
Pentaphylax, **206**, 207.
Pentapterygium, **824**, 827.
Pentapyxis, 758.
Pentarhaphia, 1002.
Pentas, 775.
Pentaspadon, 461.
Pentathymelaea, 1178.
Pentatropis, 924.
Pentodon, 775.
Pentstemon, 988.
Pentstemonacanthus, 1023.
Peperomia, **1122**, **1124**, 1127, **1130**.
Peplis, 654.
Peponium, 691.
Pepper, 1127.
Peppermint, 1051.
Pera, 1234, 1235.
Peracarpa, 816.
Perama, 775.
Peraphora, 57.
Pereae, 1223, 1225.
Perebea, 1270.
Pereskia, 156, 705.
Perforated ray cells, 107, 122, 123, 364, 446, 678, 893, 909, 912, 1221, 1227, 1321.
Perforated vessel pits, *see* ‘Vessels’.
Pergularia, 924.
Periandra, 533.
Periblema, 1023.
Pericampylos, 57.
Periclinal chimaera, 518.
Pericopsis, **520**, 534.
Pericycle, in stem, with little or no sclerenchyma, 1340.
‘Pericyclic’ sclerenchyma, xx.
Peridiscus, 127.
Perilla, 1052.
Periloma, 1052.
Periploca, **910**, 924.
Peristrophe, 1023.
Pernettya, 836.
Peroba, 1011.
Peroba Rosa, 916.
Peronema, 1041.
Perovskia, **1046**, 1052.
Perrieria, 325.
Perrottetia, 397.
Persea, **1148**, 1155.
Persicaria, 1100.
Persimmon wood, 886.
Persoideae, 1149, 1153.
Persoonia, **1166**, 1168, 1169.
Pertya, 803.
Peruvian Coca, 275.
Peruvian Nutmegs, 1144.
Peschiera, 917.
Petalonyx, 669, **670**.
Petalostemon, 533.
Petalostigma, 1234, 1235.
Petastoma, **1008**, 1011, 1013.
Petersia, 636.
Petersianthus, 636.
Petiole, stone cells in, 45, 50.
Petiole, types of vascular structure in, xiii, xvi, 1335–8.
Petitia, 1041.
Petiveria, 1091.
Petrea, **1028**, **1034**, 1040, 1041.
Petrophila, 1168.
Petroselinum, 724.
Petrosimonia, **1076**, 1084.
Petteria, 533.
Petunga, 775, 776.
Petunia, 978.
Peucedanum, 724.
Peumus, 16, 1144, **1148**, 1153, 1159, 1252.
Pfaffia, 1074.
Pfeiffera, 705.
Phacelia, **940**, 945.
Phaenocoma, 803.
Phaeophyceae, 1101.
Phaeoptilum, 1067.
Phagnalon, 803.
Phaleria, **1172**, 1178.
Pharbitis, 964.
Pharbitis seeds, 964.
Phaseoleae, **504**, 505, 514.
Phaseolus, 533.
Phaulothamnus, 1091.
Phaylopsis, 1023.
Phebalium, **306**, 316.
Phelline, 385.
Phellodendron, 316.
Phelloderm, intumescences arising from, 351.
Phelloid cells, 615, 620, 624, 651, 664, 665, 1033, 1040.
Phialodiscus, 430.
Philadelphus, **556**, **558**, **576** 577, 740.
Philgamia, 285.
Philippia, 836.
Phillyrea, **888**, 900.
Phlebocalymna, 366.
Phlebochiton, 461.
Phlebotaenia, 138.
Phloem, included (interxylary), xxvii, 1343, 1352.

Phloem, interfascicular, 1099.
Phloem, intraxylary, 1343.
Phloem, lignified, 789.
Phloem, sieve tubes absent from, 1081, 1102.
Phloem stratified, 37, 46, 112, 113, 114, 204, 212, 215, 219, 222, 227, 235, 236, 242, 247, 254, 260, 262, 267, 268, 274, 282, 336, 352, 416, 433, 481, 493, 514, 530, 547, 620, 623, 632, 683, 949, 1005, 1135, 1185, 1208, 1217, 1265, 1273, 1307, 1311, 1317, 1319.
Phloem, triangular strands of, 46, 161, 212, 215, 224, 227, 235, 236, 242, 247, 254, 255, 260, 262, 263, 538, 547, 632, 659, 1169, 1171, 1176.
Phloeotracheids, 1200.
Phlogacanthus, 1023.
Phlomis, **1044,** 1052, 1053, **1058.**
Phlox, **940,** 942.
Phoebe, 1155.
Pholidia, 1027.
Pholisma, 851.
Phoradendron, **1180, 1192,** 1194.
Phornothamnus, 648.
Phosphoric acid, 709.
Photinia, 549.
Phrodus, 978.
Phryganocydia, 1011.
Phrygilanthus, 1194.
Phryma, 1040.
Phthirusa, 1194.
Phygelius, 988.
Phylica, 411, 413.
Phyllachne, 807.
Phyllagathis, 648.
Phyllantheae, 1209, 1212.
Phyllanthinae, 1213, 1221.
Phyllanthoideae, 348, 1208, 1219, 1221, 1222, 1223, 1227, 1229, 1230, 1231, 1234.
Phyllanthus, 1234, 1235.
Phyllarthron, 1011.
Phyllichnies, 1295.
Phyllis, 775.
Phylloboea, 1002.
Phyllocactus, **700.**
Phyllochlamys, 1270.
Phylloclades, 517, 1092, 1097, 1198.
Phyllocosmus, 273.
Phyllodes, 476, 477, 480, 518.
Phyllodineae, 479.
Phyllodoce, 836.
Phyllonoma, 568.
Phyllostegia, 1053.
Phyllostylon, 1278.
Phyllota, 533.
Phylloxylon, 533.
Physalis, **968,** 978.
Physedra, 691.
Physena, 127.
Physocalymma, 654.
Physocarpus, 549.
Physochlaina, 978.
Physostegia, **1044, 1046,** 1052.
Physostigma, 533.
Phyteuma, **812,** 816.
Phytocrene, **370,** 376.
Phytocreneae, 370, 373, 374, 375.
Phytolacca, 815, 816, 975, 1091, **1096.**
Phytolaccaceae, 152, 314, 711, 772, 975, 1066, 1086–91.
Picardaea, 776.
Pickeringia, 534.
Picorrhiza, 988.
Picraena, 325.
Picralima, **904, 910,** 917.
Picramnia, **318,** 325.
Picramnioideae, 320, 325.
Picrasma, 325.
Picrella, 325.
Picridium, 803.
Picris, **784,** 803.
Picrodendraceae, 325.
Picrodendron, 325.
Picrolemma, 325.
Pictetia, 533.
Piddingtonia, 821.
Pieris, **824, 828,** 836.
Pilea, **1244,** 1253.
Pileanthus, 630.
Pileostegia, 577.
Pilocarpus, 316.
Pilosperma, 178.
Pilostyles, 1113.
Pimelandra, 871.
Pimelea, 1178.
Pimeleodendron, 1235.
Pimenta, **624,** 630.
Pimpinella, 724.
Pinckneya, 775, 776.
Pineda, 127.
Pinguicula, **992,** 994.
Pink Ivory, 410.
Pinks, 152.
Pinnatae, 446, 475.
Pinonieae, 1065.
Pintoa, 292.
Piper, **1122, 1124,** 1127, **1130.**
Piperaceae, 39, 1120–7, 1127, 1128, 1131, 1322.
Piperales, 39, 1126.
Piptadenia, **482,** 487.
Piptanthus, 533.
Piptocalyx, 1144.
Piptocarpha, 803, 804.
Piptolepis, 803.
Pipturus, 1253.
Piranhea, 1235.
Piratinera, 1270.
Piriqueta, 674.
Piscidia, 533, 534.
Piscidia Erythrina Bark, 531.
Pisonia, **1058, 1060, 1064,** 1067.
Pistachio nuts, 460.
Pistacia, **450, 456,** 461.
Pisum, 533.
'Pitcher Plants', 1105.
Pith, diaphragms in, 1342.
Pith, Elder, 757.
Pith, fibres in, 227, 302, 730, 883, 921, 1097, 1217.
Pith flecks (in wood), 564.
Pith, isolated vessels in, 298.
Pith, sclereids in, **27,** 141, 222, 856, 861, 1237.
Pith, sclerosed cells in, 67, 125, 344, 423, 449, 537, 653, 661, 672, 721, 908, 936, 942, 969, 1035, 1049, 1165, 1185.
Pith, stone cells in, 37, 44, 46, 51, 139, 283, 288, 352, 378, 392, 400, 423, 615, 643, 697, 883, 885, 921, 928, 960, 977, 984, 1057, 1135, 1149, 1165, 1173, 1219.
Pith, Taccarda, 809.
Pith, vessels in, 1021.
Pithecoctenium, 1011, 1013.
Pithecolobium, **482,** 487.
Pithecoseris, 803.
Pits, vestured, 1350.
Pittosporaceae, 128–31, 586.
Pittosporopsis, 376.
Pittosporum, **120, 130,** 131.
Pituranthos, 724.
Pityopus, 840.
Pityranthe, 262.
Pityrodia, **1028,** 1040.
Placodiscus, **426,** 430.
Plagianthus, 233.
Plagiopteron, 127.
Plagioscyphus, 430.
Planchonella, 338, 880.
Planchonia, 636.
Planera, **1274,** 1278.
Plane trees, 1281.
Plantaginaceae, 1053–9.
Plantago, 722, **1054, 1058,** 1059, **1062.**
Plasticity of characters, xii.
Platanaceae, 1278–82.
Platanus, **1250, 1280,** 1281.
Platea, **368,** 376.
Plathymenia, 487.
Platonia, 178, 179.
Platycarpum, 776.
Platycarya, **1280,** 1290.
Platycentrum, 648.
Platycodon, 816.
Platycrater, 577.
Platycyamus, 533, 534.
Platydesma, 316.
Platylobium, 533.
Platylophus, **562,** 564.

Platymiscium, 533, 534.
Platymitium, **902**, 903.
Platymitra, 49.
Platyosprion, 533.
Platypodium, 533, 534.
Platystemma, 1002.
Platystemon, 78.
Platystigma, 78.
Platytheca, **130**, 132.
Plecospermum, 1270.
Plectranthus, 1052, 1053.
Plectrocarpa, 292.
Plectronia, 775, 776.
Pleiocarpa, 917.
Pleiochiton, 648.
Pleiococca, 316.
Pleiogynium, 461.
Pleisopilos, 711.
Plenckia, 397.
Pleodendron, 111.
Pleogyne, 57.
Pleonotoma, 1011.
Plerandra, 735.
Plethiadenia, **312**, 316.
Plethiandra, 648.
Pleuricospora, 835.
Pleurisanthes, 376.
Pleurocalyptus, 630.
Pleurogyna, 939.
Pleurophora, 654.
Pleurostylia, 397.
Pleurothyrium, 1155.
Plinthus, 711.
Plocama, 775.
Plocosperma, 932.
Ploiarum, **186**, 190.
Plukenetia, **1211**.
Plukenetiinae, 1209.
Plum, 548.
— Coco, 553.
— Date, 886.
— Marmalade, 879.
Plumbaginaceae, 147, 852–7.
Plumbago, **854**, 857.
Plumeria, **910**, 917.
Plumiereae, 909.
Pneumatophores, 251, 356, 609, 662, 663, 695, 1030, 1039.
Pneumatothodes, 695.
Podachaenium, 803.
Podalyria, 533, 534.
Podalyrieae, 508, 509, 511.
Podolepis, 803.
Podonephelium, 430.
Podophyllaceae, 6.
Podophyllin, 62.
Podophyllum, 63, **66**.
Podopterus, 1100, 1101.
Podostemaceae, 1101–4.
Podostemon, 1104.
Podotheca, 803.
Poecilandra, 338.
Poecilanthe, 533, 534.
Poecilochroma, 978.
Poeciloneuron, **176**, 178, 179.
Poeppigia, 501.
Poga, **608**, 611, 612.
Poggea, 127.
Pogonanthera, 648.
Pogonophora, **1226**, 1234, 1235.
Pogonopus, 775, 776.
Pogostemon, 1052, 1053.
Poinciana, 501.
Poincianella, 501.
Poiretia, 533.
Poison Ivy, 452.
Poitaea, 533.
Polanisia, 94.
Polemoniaceae, 162, 939–43.
Polemonium, **940**, 942.
Poliomintha, 1052.
Poliothyrsis, 127.
Pollichia, 152.
'Po lom Pom' fibre, 233.
Polpoda, 711.
Polyachyrus, 803.
Polyalthia, 49.
Polycardia, 397.
Polycarpaea, 152, **154**.
Polycarpeae, 149.
Polycarpon, 152.
Polycephalium, 376.
Polycnemoideae, 1079.
Polycnemum, 1084.
Polygala, **130**, 138.
Polygalaceae, 131, 133–8, 139, 142, 145, 284, 361, 538.
Polygaleae, 133.
Polygonaceae, 151, 1092–101.
Polygonella, 1100.
Polygonum, **1096**, 1100.
Polylepis, 549.
Polymeria, 964.
Polymnia, 803.
Polyosma, **562**, 568.
Polyphyletic origin of angiosperms, 1067.
Polypompholyx, 994.
Polyporandra, 376.
Polypremum, 932.
Polyscias, **728**, **732**, 735.
Polysphaeria, 775.
Polyura, 775.
Pomaderris, 411, **412**, 413.
Pomarea, 501.
Pomegranate, 657, 660.
Pometia, **426**, 430.
Pomme d'Or, 680.
Pomoideae, 545, 546, 548.
Poncirus, 316.
Pongamia, **504**, 533, 534.
Poon, 178.
Poonspar, 178.
Poplars, 1319.
Poplar, Yellow, 19.
Poponax, 487.
Popowia, 49.
Populus, 1303, **1318**, 1320, **1322**.
Porana, **402**, 964.
Poraqueiba, 376, 377.
Porlieria, 292.
Porocystis, 430.
Porophyllum, 803.
Porospermum, 735.
Portlandia, 775.
Portulaca, **154**, 156, **160**.
Portulacaceae, 152, 153–6, 705, 1085.
Portulacaria, 156.
Portulacoideae, 155.
Posoqueria, 775, 776.
Potalia, 932.
Potamoganos, 1013.
Potato, 973.
Potato, Sweet, 963.
Potentilla, **542**, 549.
Poteranthera, 648.
Poterium, **542**, 549.
Poulsenia, 1270.
Poupartia, 461.
Pourouma, 1270.
Pourthiaea, 549.
Pouteria, **874**, 880.
Prainea, 1271.
Prangos, 724.
Prasium, 1052, 1053.
Pratia, **818**, 821.
Premna, **1036**, 1040, 1041.
Prepusa, 939.
Preslia, 1052.
Prevostea, 964.
Prickly Ash Bark, 315.
Prickly Pear, 705.
Priestleya, 533.
Primavera, 1011.
Primula, **860**, 862.
Primulaceae, 147, 857–62.
Primulina, 1002.
Prinsepia, 549.
Prionotes, 847.
Prioria, 501.
Priotropis, 533.
Prismatocarpus, 816.
Prismatomeris, 776.
Pristimera, 403.
Priva, 1040.
Privet, 899.
Prockia, 127, 1322.
Procrideae, 1246, 1247, 1249.
Pronaya, 131.
Proserpinaca, 599.
Prosopanche, 1113.
Prosopis, 487, **536**, 850.
Prosopostelma, 924.
Prostanthera, 1053.
Protea, **1164**, 1168, 1169.
Proteaceae, 611, 1160–9, 1188.
'Proteid bodies' in Cactaceae, 703.
Protein bodies, crystalline, 981.
Protium, **342**, **346**, 349.
Protomegabaria, 1235.
Protorhus, 461.
Protoschwenkia, 978.
Protostele, xxxi.

Proustia, **792**, 803, 804.
Prunella, 1053.
Pruno, 253.
Prunoideae, 545, 546, 547, 548.
Prunus, **542**, **544**, 549.
Psammea, 827.
Psammisia, 827.
Psammotropha, 711.
Psathura, 775.
Psedera, 419.
Pseudagrostistachys, 1235.
Pseudarthria, 533.
Pseudellipanthus, 476.
Pseuderanthemum, 1023.
Pseudima, 430.
Pseudobaeckea, 595.
Pseudoblepharis, **1020**, 1023.
Pseudocalyx, 1023.
Pseudocarapa, 358.
Pseudocarpidium, 1041.
Pseudocedrela, 358.
Pseudocinchona, 776.
Pseudoconnarus, 476.
Pseudocopaiva, 501.
Pseudocydonia, 549.
Pseudolachnostylis, 1234.
Pseudolmedia, 1270, 1271.
Pseudomonas citri, 308.
Pseudomorus, **1266**, 1270, 1271.
Pseudonephelium, 430.
Pseudopanax, 735.
Pseudosamanea, 487.
Pseudosciadium, 735.
Pseudosmodingium, 461.
Pseudospondias, 461.
Pseudostreblus, **1264**, 1271.
Pseudowintera, 29.
Psidiopsis, 630.
Psidium, 630.
Psilotrichum, 1074.
Psiloxylon, 127.
Psophocarpus, 533.
Psoralea, **472**, 533.
Psorospermum, 169.
Psychotria, 775, 776.
Psyllocarpus, 775.
Ptaeroxylon, **354**, 357, 358.
Ptelea, 316.
Ptelcocarpa, 954.
Pteleopsis, 620.
Pteralyxia, 917.
Pterandra, 285.
Pteranthus, 152.
Pteridophyllum, 78.
Pteridospermae, 29.
Pternandra, 648.
Pterocarpus, **504**, **522**, 533, 534.
Pterocarya, **1280**, **1286**, 1290.
Pterocelastrus, **392**, 397.
Pterochrosia, 917.
Pterocladon, 648.
Pterocymbium, **246**, 253.
Pterodon, 533, 534.
Pterogastra, 648.
Pterogyne, 501.
Pterolepis, 648.
Pterolobium, 501.
Pteropyrum, 1100.
Pterorhachis, 358.
Pterospermum, 253.
Pterospora, 834, 835, 840.
Pterostegia, 1100.
Pterostyrax, **888**, 890.
Pterotropia, 735.
Pterygopodium, 501.
Pterygota, 253.
Ptilochaete, 285, **290**.
Ptilotus, 1074.
Ptychopetalum, 366.
Ptychopyxis, 1235.
Pueraria, 533, 534.
Pulicaria, 803.
Pullea, 564.
Pulmonaria, **950**, 954.
Pulsatilla, 7.
Pultenaea, 533.
Punica, **652**, **658**, 660.
Punicaceae, 657–60.
Pupalia, 1074.
Purdieanthus, 939.
Purpleheart, 500.
Purpurella, 648.
Purshia, 549.
Putoria, 775.
Putranjiva, **1218**, 1234, 1235.
Putterlickia, 397.
Pycnanthemum, 1053.
Pycnanthus, 1138.
Pycnarrhena, 58.
Pycnobotrya, 917.
Pycnocoma, 1235.
Pycnophyllum, 152.
Pycnospora, 533.
Pycnostachys, 1053.
Pygeum, **544**, 549.
Pyinkado, 486.
Pyinma, 654.
Pyracantha, 549.
Pyramia, **640**, 648.
Pyramidocarpus, 127.
Pyrenacantha, 376, 377.
Pyrenaria, 190, 191.
Pyrethrum, 799.
Pyrethrum, 803.
Pyrethrum Root, 802.
Pyrola, 834, 836.
Pyrolaceae, 834, 835.
Pyrostegia, **1004**, 1011.
Pyrostria, 775.
Pyrrhopappus, 803.
Pyrularia, 1201.
Pyrus, **542**, 549.
Pyxidanthera, 850.

Qualea, 142, **144**.
Quapoia, 178.
Quararibea, 241.
Quassia, 325.
Quassia Chips, 325.
Quebracho Bark, 915.
Quebracho Blanco, 916.
Quebracho Wood, 461.
Queensland Hemp, 233.
Quercus, 1299, **1302**, **1306**, **1312**, 1315.
Quiina, **166**, **176**, 181.
Quiinaceae, 179–81.
Quillaja, 549.
Quillaja Bark, 548.
Quina de Rio, 773.
Quina de Sao Paulo, 977.
Quina do Matto, 773.
Quina du Brésil, 773.
Quinchamalium, 1201.
Quinine, 772.
Quintinia, **562**, 568.
Quisqualis, 620.
Quivisia, 358.

Radial canals (in wood), 1353.
Radial channels (in wood), 259, 1174, 1227.
Radiola, 273.
Rafflesia, 1113.
Rafflesiaceae, 1111–13.
Rafnia, 534.
Raillardia, 804.
Raimannia, 668.
Raisins, 419.
Ramatuela, 620.
Ramie, 1253.
Ramischia, 836.
Ramondia, **998**, 1002.
Ranales, 15, 111.
Randia, 775, 776.
Randonia, 97.
Ranunculaceae, 1–7, 62, 66, 76, 77, 78, 860, 861.
Ranunculaceous stomata, xiv.
Ranunculus, **2**, 7.
Raoulia, 803.
Rapanea, 385, **866**, **868**, 871.
Rape, 86.
Raphanistrocarpus, 691.
Raphanus, 87.
Raphides, 1345.
Raphides (in wood), l, 1066, 1354.
Raphiolepis, **542**, **544**, 549.
Rapona, 964.
Raputia, 316.
Raspberry, 548.
Raspilia, 595.
Ratonia, 430.
Rauwolfia, 917.
Ravenia, 316.
Ravensara, 1155.
Rawsonia, 127.
Rays (in wood):
— absent, xliv, 101, 107, 151, 295, 404, 794, 985, 1001, 1073, 1082, 1099.
— aggregate, xxxiv, xxxv, 373, 428, 770, 846, 1050, 1151, 1225, 1299, 1304, 1308, 1313.
— bast in, 141.
— cells perforated, *see* 'Perforated ray cells'.

Rays (in wood):
— compound, xxiv.
— fibres in, 525.
— heterogeneous, xxv, xliii.
— homogeneous, xxv, xliii, xlv, xlvi, xlviii.
— interfascicular, 93, 401, 524, 1038, 1117.
— Kribs's types, xliii.
— number, xxv, 1362.
— secretory pockets, 719.
— spirally thickened, 143.
— storied, 1352.
— tile cells, 230, 231, 239, 365.
— two sizes, l.
— types, xliii.
— vessels in, 525.
— width, xxi, xxv, l, 1362.
Rays, medullary (small stems):
— broad, 1340.
— distal ends enlarged or triangular, 35, 46, 112, 114, 119, 212, 224, 227, 235, 236, 247, 257, 260, 262, 331, 449, 514, 530, 538, 632, 659, 949, 1141, 1165, 1171, 1176, 1197, 1279, 1282, 1283, 1286, 1292.
— distal ends sclerosed, 1311.
— narrow, 1341.
— narrow and broad, 1341.
Rays, medullary (small stems and roots), absent, 83, 87, 145, 152, 861, 935, 942, 979, 984, 985, 987, 1029, 1056.
Ray-tracheids, 525, 911.
Reaumuria, 159.
Recordoxylon, 501.
Red Els, 564.
Red Ivory, 410.
Red Meranti, 220.
Red Oak, 1314, 1315.
Red Sanders, 533.
Reevesia, 253.
Regelia, 630.
Rehmannia, 988.
Reichenbachia, 1067.
Reinwardtia, **270**, 273.
Reinwardtiodendron, 358.
Reissekia, 411.
Relbunium, 775.
Relhaniinae, 795.
Remijia, 775, 776.
Rengas, 461.
Reseda, **96**, 97. [470.
Resedaceae, 94, 95–7, 305,
Resin canals, 1349.
Resin cells, 1347.
Resin, Guaiacum, 291.
Resin plates (in wood), 846.
Retama, 534.
Reticulate parenchyma (in wood), xxiv, 47, 122, 364, 673, 892, 944.
Reticulate perforation plates, xli, 23, 107, 122, 135, 201, 209, 211, 294, 304, 446, 451, 545, 571, 590, 608, 633, 703, 793, 846, 951, 1006, 1036, 1065, 1135, 1304.
Retiniphyllum, 775, 776.
Reynoldsia, 735.
Reynosia, 411, 413.
Rhabdodendron, 316, **1088**, 1091.
Rhabdostigma, 775.
Rhabdothamnus, **998**, 1002.
Rhacoma, 397.
Rhagodia, 1084.
Rhamnaceae, 131, 404–13.
Rhamnella, 411, 413.
Rhamnidium, 413.
Rhamnoneuron, 1178.
Rhamnus, **408**, **412**, 413.
Rhaphiostylis, 377.
Rhaphithamnus, 1040, 1041.
Rhaptopetalum, 268.
Rhatany, 538.
Rhazya, 917.
Rheedia, **174**, 178, 179.
Rheum, **1096**, 1100.
Rhexia, 648.
Rhigiophyllum, 816.
Rhinacanthus, 1023.
Rhinanthus, 988.
Rhipsalis, 156, 705.
Rhizanthes, 1113.
Rhizophora, 204, **604**, **606**, 611, 612, 1022.
Rhizophoraceae, 275, 601–12, 1022.
Rhizophoreae, 602, 610.
Rhodamnia, **626**, 630.
Rhodesian 'Teak', 501.
Rhodochlaena, 223.
Rhododendron, **824**, **828**, 836.
Rhododendrons, 827, 835.
Rhodoleia, **590**, 592.
Rhodomyrtus, 630.
Rhodoreae, 829.
Rhodosepala, 648.
Rhodosphaera, **456**, 461.
Rhodothamnus, 836.
Rhoideae, 459.
Rhombophyllum, 711.
Rhopalocnemis, 1207.
Rhopalopilia, 381.
Rhubarb, 1099.
Rhus, **450**, **456**, 461, 468.
Rhynchanthera, 648.
Rhynchoglossum, 1002.
Rhyncholacis, 1104.
Rhynchosia, **508**, 534.
Rhynochodia, 917.
Rhyticaryum, 377.
Rhytidophyllum, **1000**, 1002.
Rhytigynia, 776.
Ribes, **556**, 567, 573, **576**.
Rice paper, 734.
Richardsonia, 775.
Richea, **842**, 847, **848**.
Richeria, **1218**, 1234.
Ricinocarpoideae, 1228.
Ricinocarpos, 1234.
Ricinodendron, **1226**, 1235.
Ricinus, **1216**, **1226**, 1234, 1235.
Rigiostachys, **318**, 325.
Rimaria, 711.
Ring-porous woods, xlvi, xlvii, 1350.
Rinorea, 108.
Ritchiea, 94.
Rivea, 964.
Rivina, 1091.
Robinia, 534.
Roble, 1011.
Rochea, 581.
Rochefortia, 954.
Rockia, 1067.
Rock Maple, 435.
Rodgersia, 557.
Rodigia, 803.
Roella, 816.
Roemeria, 78.
Rogeria, 1014.
Rolandra, 803.
Rollinia, 49.
Romanzoffia, 945.
Romneya, **76**, 78.
Rondeletia, **764**, 775, 776.
Root hairs, 68, 70, 136, 187, 797.
Root hairs absent, 628, 797, 819, 861, 936, 989, 990.
Root hairs lignified, 861.
Root hairs, persistent, 797.
Root nodules, 410, 503, 527, 827, 833, 986, 1187, 1291, 1293, 1299, 1304.
Root tubercles, *see* Root nodules.
Roots, bacteria in, 499, 527, 1187.
Roots, buttress, 235, 240, 251.
Roots, contractile, 300, 302.
Roots, exogenous origin of, 851.
Roots, fungal hyphae in, 5, 291.
Roots, influence of soils on structure, 151, 233.
Roots, negatively geotropic, 612, 619, 660, 662.
Roots, thickening ridges in, 293, 295, 609, 839.
Roots, vertical, 660, 662.
Roots with exogenous cork, 797.
Rootstocks, Apple, 547.
Root-thorns, 1207, 1228.
Roridula, 586.
Roridulaceae, 586.
Rosa, **542**, **544**, 549.
Rosaceae, 15, 16, 19, 314, 361, 475, 539–53, 553, 555, 568, 833.

Rosaceae (Chrysobalanoideae), 550–3.
Rosaceae (excluding Chrysobalanoideae), 539–50, 833.
Rosa de madera, 1194.
Rosa de Palo, 1194.
Rosales, 16, 568.
Rose, American Pillar, 543, 547.
Rose Apple, 629.
Rose, Christmas, 16.
Rose, Dorothy Perkins, 543.
Rose Mahogany, 357.
Rosemary, 1051.
Rosewood, 533.
— Brazilian, 533.
— Honduras, 533.
— Indian, 533.
Rosmarinus, 1053, **1058**.
Rosoideae, 545, 548.
Rostellaria, 1023.
Rotenone, 529.
Rothia, 534.
Rotula, 954.
Roubieva, 1084.
Roucheria, 273.
Roupala, 1168, 1169.
Rourea, 476.
Roureopsis, 476.
Roussea, 568.
Rousseauxia, 648.
Roydsia, 95.
Royena, **878**, 886.
Rozelle Hemp, 233.
Rubber, xviii, xix, 31, 34, 125, 389, 396, 399, 403, 404, 623, 702, 786, 800, 801, 872, 915, 924, 1270.
Rubber, Ceara, 1232.
— Para, 800, 1231, 1271.
Rubbery wood of apples, 549.
Rubia, **764**, 775.
Rubiaceae, 108, 385, 759–76, 1233.
Rubiaceous stomata, xiv.
Rubus, **542**, 549.
Rudbeckia, 803.
Rudgea, 385, 775, 776.
Rudolphia, 534.
Ruellia, 1023.
Ruellieae, 1017.
Rue, Oil of, 314.
Rulingia, 253.
Rumex, **1096**, 1100.
Ruprechtia, **1088**, 1100, 1101.
Rusbyanthus, 939.
Ruschia, 711.
Russelia, 988.
Rustia, 775.
Ruta, 316, **334**.
Rutaceae, 305–16, 329, 347, 348, 356, 357, 429.
Rutidia, 776.
Rutoideae, 313.
Ruyschia, 203.
Ryania, **120**, 127.
Ryparosa, 127.
Ryssopterys, 285.

Sabbatia, 939.
Sabia, **444**, 452.
Sabiaceae, 446, 448–52.
Sabicea, 775.
Sabinea, 534.
Saccellium, **952**, 954.
Saccharum, 991.
Saccoglottis, **276**, 279.
Saccopetalum, 49.
Sacs, secretory, 1348.
Sage, 1051.
Sageraea, 49.
Sageretia, 413.
Sagina, 152.
Sagotia, 1235.
Sagraea, 648.
Sahagunia, 1270.
St. Helena Tea, 147.
St. Ignatius Beans, 932.
Saintpaulia, 1002.
Sakakia, 191.
Sakersia, 648.
Salacia, **382**, **388**, **402**, 403.
Salazaria, 1053.
Salicaceae, 1289, 1308, 1315–20.
Salicornia, 706, **1080**, 1084.
Salicornieae, 1081.
Salix, **1318**, 1320, **1322**.
Salomonia, 138.
Salpichroa, 978.
Salpiglossis, 978.
Salpinga, 648.
Salsify, 799.
Salsola, **1078**, 1084.
Salsoleae, 1081.
Salvadora, **890**, **892**, **902**, 903, **904**.
Salvadoraceae, 900–3.
Salvertia, 142.
Salvia, 1053, **1058**.
Samadera, 325.
Samanea, 487.
Samba, 253.
Sambucaceae, 757.
Sambucus, **756**, 758, 975.
Samolus, 862.
Samples of wood, lv.
Samyda, 127.
Samydaceae, 116, 125, 1230.
Sanchezia, **1016**, **1020**, 1023.
Sandalwood, 803, 1027, 1201.
Sanders Wood, Red, 533.
Sandoricum, 358.
Sanguinaria, 78.
Sanguisorba, 549.
Sanicula, **716**, 724.
Santalaceae, 379, 381, 1195–1201, 1202, 1203, 1206.
Santaloides, 476.
Santalum, **1198**, 1201.
Santa Maria (wood), 178.
Santiria, **342**, **346**, 349.
Santolina, **790**, 803, 804.
Santonica, 802.
Sanvitalia, 803.
Sapele Mahogany, 357.
Sapindaceae, 314, 347, 348, 356, 357, 419–31, 435, 439, 440, 441, 443, 446, 448, 451, 459, 475.
Sapindales, 375, 443, 463, 467, 475.
Sapindus, **426**, 430.
Sapium, 1235.
Sapodilla, 879.
Saponaria, 152, **160**.
Saponin, 152, 156, 420, 422, 511, 703.
Sapotaceae, 871–80, 886.
Sapranthus, 49.
Saprosma, 775.
Sapucaia Nuts, 636.
Saraca, 501, **536**.
Saracha, 978.
Sarcobatus, **1072**, 1084.
Sarcocaulon, 297, 579.
Sarcocephalus, **764**, **768**, 775, 776.
Sarcochlaena (*Sarcolaena*), **208**, 223.
Sarcoclinium, 1235.
Sarcococca, **1238**, 1241.
Sarcocolla, 529, 1183.
Sarcodes, 835, 840.
Sarcomphalus, 413.
Sarcopetalum, 58.
Sarcophyte, 1207.
Sarcopteryx, 430.
Sarcopyramis, 648.
Sarcosperma, **874**, 880.
Sarcospermaceae, 879.
Sarcostemma, 924.
Sarcostigma, 376, 377.
Sarcostigmateae, 368, 370, 373, 374, 375.
Sarcotheca, 303.
Sarcotoechia, 430.
Sargentodoxa, 66, 67.
Sargentodoxaceae, 67.
Sarothamnus, **522**, 534.
Sarracenia, **72**, 74, 560, 1111.
Sarraceniaceae, 71–4, 1111.
Sarsaparilla, 734, 924.
Saruma, 1119.
Sassafras, **1148**, 1155.
Sassafras bark, 1154.
Sassafras wood, 1144.
Sassafridium, 1155.
Satinay, 630.
Satiné, 1269.
Satinwood, 314.
Satureia, 1053.
Satyria, 827, 836.
Saurauia, 10, **182**, **192**, **202**, **208**, 210.
Saurauiaceae, 10, 126, 209–10.
Sauropus, 1235.
Saururaceae, 1126, 1127–8, 1131.

Saururus, 1126, 1128.
Sausage Tree, 1011.
Saussurea, 803.
Sautiera, 1023.
Sauvagesia, 108, 338.
Sauvagesieae, 108.
Savia, 1234, 1235.
Savignya, 87.
Saxifraga, **556**, 557.
Saxifragaceae, 547, 553–7, 564, 567, 573, 577, 777, 850.
Scabiosa, **778**, 781.
Scaevola, 809.
Scalariform intervascular pitting, *see* 'Vessels'.
Scalariform perforation plates, xli, xlii, 1342, 1349.
Scales, peltate, 1329.
Scaligeria, 724.
Scammony Root, 964.
Scanty paratracheal parenchyma (in wood), xxiv.
Scaphium, **246**, 253.
Scaphopetalum, 253.
Schaefferia, 397.
Schaueria, 1023.
Schefflera, 735.
Schefflerodendron, 534.
Schima, **186**, 190, 191.
Schindleria, 1091.
Schinopsis, **450**, 461.
Schinus, **450**, **456**, 461.
Schisandra, 25, **32**.
Schisandraceae, 21–5, 26, 29, 42, 1137, 1143.
Schizanthus, **966**, 978.
Schizocardia, 839.
Schizochlaena (*Schizolaena*), **208**, 223.
Schizocodon, 850.
Schizolobium, 501.
Schizomeria, **562**, 564.
Schizopepon, 691.
Schizophoreae, 1223.
Schizophragma, 577.
Schlectendalia, 803.
Schlegelia, 1011, 1013.
Schleichera, **426**, 430.
Schleichereae, 421.
Schlumbergera, **700**, 705.
Schmaltzia, 461.
Schoenobiblus, **1172**, 1178.
Schoepfia, **360**, 366.
Schoepfioideae, 366.
Schotia, 501.
Schoutenia, 262.
Schouwia, 87.
Schradera, 775.
Schrankia, 487.
Schrebera, **898**, 900.
Schultesia, 939.
Schumacheria, 11.
Schuurmansia, 108, 338.
Schwabea, 1023.
Schwackaea, 648.
Schwalbea, 988.
Schwannia, 285.
Schweinfurthia, 988.
Schweinitzia, 840.
Schwenkia, 978.
Sciacassia, 501.
Sciadodendron, 735.
Sciadopanax, 735.
Sciadophyllum, 735.
Sciadotaenia, 58.
Scleranthus, 152.
Sclereids in cork, 730, 959, 1133.
Sclereids in cortex, 27, 140, 189, 288, 856, 861, 1237.
Sclereids in mesophyll, 29, 36, 222, 491, 641, 753, 855.
Sclereids in pith, 27, 141, 222, 856, 861, 1237.
Sclerenchymatous idioblasts (spicular cells), *see* 'Idioblasts, sclerenchymatous'.
Sclerocarya, 461.
Sclerocephalus, 152.
Sclerodictyon, 917.
Sclerolobium, 501.
Scleronema, 241.
Sclerophylax, 978.
Scleropyrum, **1198**, 1201.
Sclerosed cells in mesophyll, 133, 171, 399, 400, 405, 421, 439, 453, 473, 509, 535, 595, 641, 880, 881, 907, 1129, 1162.
Sclerosed cells in pith, 67, 125, 344, 423, 449, 537, 653, 661, 672, 721, 908, 936, 942, 969, 1049, 1165, 1185.
Sclerosed or sclerotic cells in cortex, 75, 204, 222, 386, 454, 462, 465, 566, 589, 595, 721, 748, 766, 788, 882, 999, 1025, 1047, 1081, 1089, 1141, 1243, 1265.
Sclerosed (Scleroid) cells (in wood), 10, 457, 1136, 1193.
Sclerotheca, 821.
Sclerotic epidermis, 53, 95, 134, 173, 421, 717, 721, 896, 1179, 1212.
Scolopia, 127.
Scolosanthes, 775.
Scolymus, 803.
Scoparia, 988, **1000**.
Scopolia, 978.
Scorodocarpus, 366.
Scorodophloeus, 501.
Scorpiurus, 534.
Scorzonera, 799.
Scorzonera, 803.
Scottellia, 127.
Scrophularia, **982**, 988.
Scrophulariaceae, 972, 975, 978–88, 990, 1200.
Scutellaria, 1053.
Scutellarin, 1045.
Scutia, 413.
Scutinanthe, 349.
Scybalium, 1207.
Scyphiphora, 775, 776.
Scyphocephalium, 1138.
Scyphonychium, 430.
Scytopetalaceae, 266–8.
Scytopetalum, 268, **276**.
Seaside Grape, 1100.
Sebaea, 939.
Sebastiania, 1234, 1235.
Sechium, 691.
Secretory canals, 1348.
Secretory cavities, 1348.
Secretory cells, **xix**, 1347.
Secretory idioblasts, *see* 'Idioblasts, secretory'.
Secretory pockets in wood rays, 719.
Secretory sacs, 1348.
Secretory spaces (in wood), 618.
Secretory structures, internal, 1346.
Securidaca, **136**, 138, 139, **402**.
Securigera, 534.
Securinega, 1234, 1235.
Seddera, 964.
Sedum, **558**, **570**, 581.
Seetzenia, 292.
Selaginaceae and Globulariaceae, 1027–30.
Selago, **1026**, **1028**, 1030.
Selenicereus, 705.
Selinocarpus, 1067.
Selliera, 809.
Semecarpeae, 459.
Semecarpus, 461.
Semnanthe, 711.
Sempervivum, **558**, 581.
Senaea, 939.
Senebiera, 87.
Senecio, **792**, 803, 804.
Senecioneae, 783.
Senefeldera, 1234, 1235.
Senega Root, 137.
Senna, 500.
Senna, substitute for, 924.
Senra, 233.
Septate fibres (in wood), **xlvi**, xlvii.
Septate wood parenchyma, 168, 180, 345, 373, 496, 929.
Sequieria, **1088**, 1091.
Seraya, 220.
Serianthes, 487.
Sericocarpus, **790**, 803.
Sericodes, 292.
Sericostoma, 954.
Serissa, 775.
Serjania, **424**, 430.
Serpentary, 1119.
Serpicula, 599, **600**.
Serratula, 803.
Sersalisia, **874**.
Sesamum, **1012**, 1014.
Sesamum Oil, 1014.

Sesbania, 534.
Seseli, **714**, 724.
Sessea, **966**, 978.
Sesuvium, 711.
Shantzia, 233.
Shea Butter, 879.
Shepherdia, **1186**, 1188.
Sherardia, 775.
Shoots of limited growth, 344.
Shorea, **218**, 220.
Shortia, **848**, 850.
Shuteria, 534.
Sibiraea, 549.
Sickingia, 775, 776.
Sicyos, 691.
Sida, 233.
Sidalcea, 233.
Sideritis, **1046**, 1053.
Sideroxylon, 880.
Sieve tubes absent from phloem, 1081, 1102.
Sieve tubes, lateral sieve plates in, 161, 1286.
Sieve tubes, scalariform sieve plates in, 110, 481, 1206, 1297.
Sieve tubes, sieve plates in end wall, 1292.
Sieve tubes specially large, 1081, 1097.
Silaus, 724.
Silene, 152, **154**.
Siler, 724.
Silica in pericycle, 33, 34, 551.
Silica (in wood), l, 9, 18, 122, 168, 177, 217, 237, 248, 249, 258, 311, 313, 345, 346, 347, 355, 429, 457, 458, 499, 546, 552, 605, 607, 608, 627, 635, 875, 876, 877, 1007, 1037, 1038, 1151, 1219, 1221, 1223, 1225, 1227, 1275, 1277.
Silicified cells in leaf, 10, 13, 17, 33, 55, 362, 363, 479, 551, 685, 1114, 1115, 1121, 1129, 1161, 1188, 1189, 1195, 1196, 1203, 1212, 1244, 1245, 1259, 1263, 1271, 1273.
Silk Cotton, 241.
Silky Oaks, 871, 1168.
Silphium, 803.
Silver Grey Wood, Indian, 619.
Silvia, 1155.
Silvianthus, 775.
Silybum, 803.
Simaba, **322**, 325.
Simaruba, 325.
Simarubaceae, 291, 314, 317–26, 327, 329, 332, 347, 348, 357, 429, 465, 1051.
Simarubeae, 324.
Simaruboideae, 323, 324.
Simarubopsis, 325.
Simmondsia, **1240**, 1241.
Sinapis, 87.
Sindora, 501.
Sinningia, **998**, 1002.
Sinomenium, 58.
Sinowilsonia, 592.
Sipanea, 775.
Siparuna, 16, **1140**, 1144, **1158**, 1159.
Siphanthera, 648.
Siphocampylus, 821.
Siphonodendron, 1230.
Siphonodon, 397.
Siphonoglossa, 1023.
Siphonostele, xxxi.
Siphonychia, 152.
Sison, 724.
Sisymbrium, 87.
Sium, 724.
Skimmia, 316.
Sladenia, 10, 190.
Slide collections for reference, liv.
Slippery Elm Bark, 1273, 1277.
Sloanea, **264**, 266.
Sloetia, 1270, 1271.
Smeathmannia, **676**, 680.
Smelophyllum, 430.
Smilax, 924.
Smithia, 534.
Smodingium, 461.
Smyrnium, **716**, 724.
Snake Root, 137.
— Black, 6.
— Virginian, 1119.
Snakewood, 1269
Soap Berries, 430.
Soap Root, 152.
Soaresia, 803.
Soemmeringia, 534.
Softening wood, liv.
Soft Maple, 435.
Sohnreyia, 316.
Soils, influence of on root structure, 151, 233.
Solanaceae, 757, 914, 961, 963, 965–78, 986, 1084, 1091.
Solandra, 978.
Solanophora, **1000**, 1002.
Solanum, **966**, **970**, 978.
Soldanella, 862.
Solenocarpus, 461.
Solenostemma, 924.
Solidago, 803.
Soliera, 1053.
Solitary crystals, 1343.
Sollya, 131.
Solmsia, **118**, 1178, 1181.
Somalia, 1023.
Sommera, 775, 776.
Sonchus, 803.
Sonerila, 648.
Sonneratia, **662**, 664.
Sonneratiaceae, 660–4.
Sophora, 487, 534.
Sophoreae, 505, 508.
Sophronanthe, 988.
Sorbaria, 549.
Sorbus, **542**, 549.
Sorindeia, 347, 461.
Sorocea, 1270, 1271.
Sorocephalus, 1168.
Soulameae, 318, 325.
Souroubea, 203, 340.
Southland Beech, 1315.
Soyauxia, **676**, 680.
Soymida, 358.
Spachea, 285.
Spanish Broom, 529.
Spanish Cedar, 357.
Sparattanthelium, **1158**, 1159.
Sparattosyce, 1270, 1271.
Sparmannia, 262.
Sparmannieae, 261.
Spartium, **512**, **522**, 534.
Spartothamnella, 1040.
Spathodea, 1011, 1013.
Spatholobus, 534.
Specialization, wood characters associated with, xlii–xlvi.
Specularia, 816.
Spergula, 152.
Spergularia, 152.
Spermacoce, 775.
Sphacele, 1053.
Sphaeralcea, 233.
Sphaerocrystals, 1346.
Sphaerolobium, 534.
Sphaerophysa, 534.
Sphaerosepalum, 115, 126.
Sphaerosicyos, 691.
Sphedamnocarpus, 285.
Sphenoclea, 816.
Sphenocleaceae, 815, 816.
Sphenodesma, 1040.
Sphenotoma, 847.
Sphinctanthus, 775, 776.
Spicular cells, *see* Idioblasts, sclerenchymatous.
Spigelia, 932.
Spikenard, 779.
Spilanthes, **784**, 803.
Spinach, 1084.
Spinacia, 1084.
Spiradiclis, 775.
Spiraea, **544**, 549.
Spiraeoideae, 545, 548.
Spiraeopsis, 564.
Spiral thickening in rays, 143.
Spiral thickening in tracheids, 61, 520.
Spiral thickening in wood fibres, 1352.
Spiral thickening in vessels, xlvi, xlviii, 1349.
Spiranthera, 316.
Spiropetalum, 476.
Spirostigma, 1023.
Spodograms, 1246, 1263.
Spogel Seeds, 1059.

Spondiae, 459.
Spondianthus, 1230.
Spondias, 461.
Spraguea, 156.
Sprengelia, **842**, 847.
Spyridium, 413.
Staavia, 595.
Stachyarrhena, 776.
Stachys, **1042**, **1044**, 1053.
Stachystemon, 1234.
Stachytarpheta, 1040–1.
Stachyuraceae, 210–12, 1281.
Stachyurus, **192**, **206**, 212.
Stackhousia, 404.
Stackhousiaceae, 403–4.
Stadmannia, 430.
Staehelina, 803.
Staelia, 775.
Stahlia, 501.
Stapelia, 924.
Staphylea, **438**, **444**, 447.
Staphyleaceae, 439, 443–7.
Star Anise, 25.
Star Apple, 879.
Starch, diagnostic value of, xviii.
Staudtia, **1134**, 1138.
Stauntonia, 66.
Stauranthera, 1002.
Steganotaenia, **718**, 724.
Stegnosperma, 1091.
Stelar structure and Phylogeny, xxxi.
Stelechocarpus, 49.
Stele, polyfascicular, xxxi.
Stellaria, 152.
Stellate cells in mesophyll, 149, 1146.
Stellera, 1178.
Stemmadenia, 917.
Stemonoporus, 220.
Stemonurus, 376, 377.
Stenandrium, 1023.
Stenanona, 49.
Stenanthera, 49.
Stenocarpus, **1164**, 1168, 1169.
Stenodon, 648.
Stenolobeae, 1217.
Stenolobium, 1013.
Stenopadus, 804.
Stenosolen, 917.
Stenostomum, 776.
Stephania, **54**, 58.
Stephanodaphne, 1178.
Stephanopodium, 361.
Stephanotis, 924.
Stephegyne, 775.
Stephenophysum, **1016**.
Sterculia, **246**, 253.
Sterculiaceae, 232, 241, 242–54, 254, 257, 260.
Sterculiaceae-Buettnerioideae, 249, 252.
Sterculieae, 252.
Sterculioideae, 245.
Stereospermum, **1008**, 1013.
Sterigmapetalum, 612.
Steriphoma, **88**, 94, 95, **96**.
Stevensia, 776.
Stewartia, 190, 191.
Stifftia, 803.
Stigmaphyllon, 285.
Stilbe, 1041.
Stilbeae, 1031, 1033, 1035.
Stilbocarpa, 735.
Stillingia, 1234, 1235.
Stilpnophyllum, 775.
Stilt-roots, 601.
Stimpsonia, 862.
Stinging-nettle, 1253.
Stinkwood, 1155.
Stipulicida, 152.
Stizophyllum, 1011.
Stocksia, 430.
Stoebe, 803, 804.
Stomata, anisocytic, xv, 1332.
Stomata, anomocytic, xv, 1331.
Stomata, caryophyllaceous, xiv, 1332.
Stomata, cruciferous, xiv, 1332.
Stomata, diacytic, xv, 1332.
Stomata frequency, highest recorded, 822.
Stomata, frequency of, 69, 308, 314, 822.
Stomata in clusters, 36, 53, 149, 319, 335, 554, 693, 996, 997, 1032, 1161, 1261.
Stomata, paracytic, xv, 1332.
Stomata, ranunculaceous, xiv, 1331.
Stomata, rubiaceous, xiv, 1332.
Stomata, special types of, 1333.
Stomata, 'Tradescantia' type of, 918.
Stomata with cuticular teeth, 3, 68.
Stomata with rosettes of subsidiary cells, 53, 1120, 1121, 1127, 1169, 1179, 1236, 1261.
Stone cells, crystals in, 37, 57, 91, 116, 121, 124, 767, 1025, 1035, 1147, 1185, 1191, 1237, 1273, 1281, 1308, 1311.
Stone cells in cork, 139, 615, 808, 928, 969, 1273.
Stone cells in cortex, *see* 'Cortex, stone cells in'.
Stone cells in mesophyll, 205, 473, 491, 621, 694, 927, 1146, 1188, 1189, 1205.
Stone cells in petiole, 45, 50.
Stone cells in pith, 37, 44, 46, 51, 139, 283, 288, 352, 378, 392, 400, 423, 615, 643, 697, 883, 885, 921, 928, 960, 977, 984, 1057, 1135, 1149, 1165, 1173, 1219.
Stone cells in wood, 1167.
Storax, 592, 887, 889.
Storckiella, 501.
Storied structure (in wood), xxvii, xliv, 1352.
Stormia, 49.
Storthocalyx, 430.
Stramonium, 975.
Stranvaesia, 549.
Strasburgeria, 338.
Straussia, 776.
Strawberry, 548.
Strebleae, 1269.
Streblus, 1271.
Strephonema, 620.
Streptocarpus, **998**, 1002.
Streptopetalum, **672**, 674.
Streptosolen, **968**, 978.
Striga, 988, 990.
Strobilanthes, 1023.
Strobilopanax, 735.
Strombosia, **360**, 366.
Strombosiopsis, 366.
Strongylodon, 534.
Strophanthus, 917.
Strumpfia, 775, 776.
Struthanthus, 1194.
Struthiola, 1178.
Strychnine, 932.
Strychnos, 903, **920**, **930**, 932.
Stryphnodendron, 487.
Stuebelia, 95.
Stylidiaceae, 804–7.
Stylidium, 807, **818**.
Stylisma, 964.
Stylobasium, 553.
Styloceras, **1240**, 1241.
Stylocoryna, 776.
Stylogyne, **866**, **868**, 871.
Styloids, 1345.
Stylophorum, 78.
Stylosanthes, **508**, 534.
Styphelia, 847.
Styphelieae, 843.
Styracaceae, 887–90, 893.
Styrax, **888**, 890, **898**.
Suaeda, **1072**, 1084.
Suaedeae, 1081.
Substitute wood fibres, xxv.
Subularia, 87.
Successive cambia, 1343.
Succisa, 781.
Sugar-beet, 1083.
Sugar, Maple, 435.
Suksdorfia, 557.
Sukunia, 776.
Sumac, Cape, 1201.
Sumach, 468.
Sumach leaves, 460.
Sumbavia, 1235.
Sumbul, 724.
Sunflower, 799.
Sunn Hemp, 529.
Suriana, 325.
Surianaceae, 324, 325.
Surianoideae, 320, 324.
Sutherlandia, 534.

Svitramia, 648.
Swainsona, 534.
Swartzia, 534.
Swartzieae, 505, 507.
Swedes, 86.
Sweet Almonds, 548.
Sweet Bay, 1153.
Sweet Birch, 1305.
Sweet Cup, 680.
Sweet Gum, 592.
Sweetia, 534.
Sweet Potato, 963.
Swertia, 939.
Swietenia, **354**, 358.
Swietenioideae, 355, 356.
Swinglea, 316.
Swintonia, 461.
Sycamore wood, 435.
Sycopsis, 592.
Symbryon, 1127.
Symmeria, 1100, 1101.
Sympetalae, 162.
Symphonia, **174**, 178, 179.
Symphorema, 1041.
Symphoricarpus, **754**, 758.
Symphyandra, **812**, 816.
Symphyllia, 1234.
Symphyonema, 1169.
Symphyopappus, 803.
Symphytum, **950**, 954.
Symplocaceae, 890–3.
Symplocos, 385, **888**, **892**, 893.
Synadenium, 1234.
Synaphea, 1168.
Synaptolepis, 1178.
Syncarpia, **624**, 630.
Synima, 430.
Synoum, 358.
Synsepalum, 880.
Syntriandrium, 58.
Syringa, **888**, 900.
Syrrhonema, 58.
Systemodaphne, 1155.
Syzygium, 630.
Szinkum Mandarin, 308.

Tabebuia, **1008**, 1011, 1013.
Tabernaemontana, 917.
Tacazzea, 924.
Taccarda pith, 809.
Tachigalia, 501.
Tacsonia, 680.
Taenichlaena, 476.
Tagetes, 803.
Talauma, 21.
Talguenea, 413.
Talinum, 156.
Talisia, 430.
Tallow Wood, 630.
Tamaricaceae, 147, 157–9, 162, 164.
Tamaricales, 163.
Tamarinds, 500.
Tamarindus, **494**, 501.
Tamarix, **144**, 159, **160**, 163.
Tamarix galls, 158.
Tamarix manna, 158.
Tambourissa, **1140**, 1144.
Tammsia, 775.
Tamonea, 1041.
Tanacetum, 803.
Tanaecium, 1011.
Tangential vessel pattern, *see* 'Vessels'.
Tannic acid, 292.
Tannin cavities, 1348.
Tannin cells, 1348.
Tanning, 158, 285.
Tanniniferous tubes (in wood), **1134**, 1136, 1137.
Tapioca, 1232.
Tapirira, 461.
Tapiscia, 447.
Tapura, **350**, 361.
Taraktogenos, **120**, 127.
Taraxacum, 803.
Tarchonanthus, 803.
Tarenna, 776.
Tarrietia, **246**, 253.
Tasmanian Oak, 630.
Tasmanian Sassafras, 1144.
Tatea, 1041.
Tau-saghyz, 800.
Tavaresia, 924.
Taverniera, 534.
Taxotrophis, **1266**, 1270, 1271.
Tea, 190.
Tea, African, 396.
— Arabian, 396.
— Bush, of Queensland, 1051.
— Maté, 376, 871.
— Paraguay, 385.
— St. Helena, 147.
— Yaupon or Yapon, 385.
Tea, substitute for, 1040.
Teak, 1040.
'Teak', Cape, 932.
'Teak', Rhodesian, 501.
Teclea, **312**, 316.
Tecoma, **1004**, **1006**, 1013.
Tecomaria, 1011, 1013.
Tectona, **1034**, **1036**, 1041.
Teijsmanniodendron, 1041.
Telephium, 152.
Telfairia, 691.
Telitoxicum, 58.
Tellima, 557.
Telmatophila, 803.
Teloxys, 1084.
Tembusu, 932.
Templetonia, 534.
Tephrosia, 534.
Teramnus, 534.
Terebinthales, 207, 451, 459, 468.
Terminalia, **598**, **614**, **616**, 620.
Ternstroemia, **186**, 190, 191.
Ternstroemiaceae, 189.
Ternstroemieae, 190, 207.
Ternstroemiopsis, 190.
Tersonia, 1091.
Tessaria, 804.
Tetilla, 557.
Tetracentraceae, 42–4.
Tetracentron, 28, 34, **40**, 42, 44.
Tetracera, **8**, 11.
Tetraclis, 886.
'*Tetractomia*', 316.
Tetradenia, 1155.
Tetragastris, 349.
Tetragonia, 711.
Tetragonolobus, 534.
Tetrameles, **698**.
Tetramerista, 198, 341, **346**.
Tetrameristaceae, 339–41.
Tetrapanax, 735.
Tetraplasandra, 735.
Tetrapleura, 487.
Tetrapodenia, 285.
Tetrapteris, 285, **402**.
Tetrasida, 233.
Tetrastigma, 419.
Tetrastylis, 680.
Tetratheca, **130**, 132.
Tetrathylacium, 127.
Tetrathyrium, 592.
Tetrazygia, 648.
Tetrorchidiinae, 1231.
Tetrorchidium, **1226**, 1234, 1235.
Teucrium, 1053.
Textoria, 735.
Thalictrum, **2**, 7.
Thamnosma, 316.
Thapsia, 724.
Theaceae, 10, 126, 169, 178, 181, 181–91, 193, 195, 198, 203, 204, 205, 207, 210, 211, 278, 340, 835, 1177, 1242.
Theales, 10, 126, 190.
Thelygonaceae (Cynocrambaceae), 1258–9.
Thelygonum, 1259.
Theobroma, **244**, **250**, 253.
Theophrasta, 871.
Theophrasteae, 863, 864, 865, 867, 870, 871.
Thermopsis, 534.
Thesium, **1192**, 1201.
Thespesia, **228**, 233.
Thevetia, **904**, 917.
Thibaudia, 827.
Thibaudieae, 822.
Thiloa, 620.
Thinouia, **424**, 430.
Thitka, 261.
Thladiantha, 691.
Thonningia, 1207.
Thottea, **1116**, 1119.
Thouinia, 430.
Thouinidium, 430.
Thrincia, 803.
Thryallis, **280**, 285.
Thryptomene, 630.
Thunbergia, **1012**, **1016**, **1018**, 1023.

Thurberia, 233.
Thylachium, 94.
Thyme, 1051.
Thymelaea, 1178.
Thymelaeaceae, 285, 1169–78, 1179, 1181, 1188.
Thymelaeales, 1181.
Thymus, 1053.
Thyrsacanthus, 1023.
Thyrsodium, 461.
Tiarella, 557.
Tibouchina, **638**, **640**, **646**, 648.
Tidestromia, 1074.
Tieghemopanax, 735.
Tile cells, *see* 'Rays'.
Tilia, 215, **244**, **256**, 257, 259, 262, 336, 1258.
Tiliaceae, 113, 114, 126, 232, 241, 245, 252, 254–62, 262, 263, 265, 266, 268, 1176, 1177, 1181, 1229, 1252.
Tiliacora, 58, **60**.
Tiliales, 267, 1181.
Tillaea, 581.
Timonius, 775, 776.
Tina, 430.
Tinnea, 1053.
Tinomiscium, 58.
Tinospora, 58.
Tipuana, 534.
Tirpitzia, 273.
Tisonia, 127.
Tittmannia, 595.
Tobacco, 974.
Tococa, **640**, 648.
Tocoyena, 775, 776.
Toddalia, **306**, 316.
Toechima, 430.
Tolmiea, 557.
Toluifera, 534.
Tomato, 974.
Tooth-ache bark, 315.
Tooth-brush tree, 903.
Topobea, 648.
Torenia, **982**, 988.
Toricellia, 741.
Torralbasia, 397.
Torresia, 534.
Torrubia, **1058**, 1067.
Touchardia, 1253.
Toulicia, 430.
Tournefortia, 954.
Touroulia, **176**, 181.
Tovaria, 94.
Tovomita, 178, 179.
Tovomitopsis, **174**, 179.
Townsendia, 803.
Toxicodendron, 461.
Tozzia, 988.
Trabeculae (in wood), 1304.
Tracheids in cortex, 158.
Tracheids in mesophyll, 140, 157, 171, 641, 1039, 1195.
Tracheids (in wood), xli, xlix, 28, 42, 44, 135, 231, 259, 275, 289, 313, 361, 365, 410, 446, 451, 459, 591, 703, 778, 833, 877, 922, 1001, 1174, 1199, 1200, 1288, 1304, 1308, 1351.
Tracheids, vascular (in wood), 44, 231, 259, 365, 410, 446, 459, 778, 877, 922, 1001, 1174, 1199, 1200, 1288.
Tracheids, vasicentric (in wood), xlix, 1351.
Tracheids with spiral thickening (in wood), 61, 520.
Trachelium, 816.
Trachelospermum, **904**, 917.
Trachylobium, 501.
'*Trachymene*', 724.
Tragacanth, 529.
Tragia, **1211**, 1234, 1235.
Tragopogon, **790**, 803.
Trapa, 668.
Trapella, 1014.
Trattinickia, 349.
Treculia, **1266**, 1270, 1271.
'Tree Cyclamens', 858.
Tree Tomato, 974.
Trema, **1276**, 1278.
Tremandra, 132.
Tremandraceae, 131, 131–2, 137, 142, 145, 284, 361.
Trematanthera, 10, 190.
Trematosperma, 371, 376.
Trembleya, 648.
Tresanthera, 775.
Trevesia, **726**, 735.
Trevoa, 413.
Trewia, 1234, 1235.
Trianaea, 978.
Triangular strands of phloem, 46, 161, 212, 215, 224, 227, 235, 236, 242, 247, 254, 255, 260, 262, 263, 538, 547, 632, 659, 1169, 1171, 1176.
Trianthema, 711.
Triaspis, 285.
Tribulus, **286**, 292.
Tricalysia, 775, 776.
Tricardia, 945.
Trichadenia, 127.
Trichanthera, 1023.
Trichilia, 358.
Trichocaulon, 924.
Trichocereus, 705.
Trichocladus, **590**, 592.
Trichodesma, 954.
Trichodiadema, 711.
Trichosanthes, 691.
Trichoscypha, 461.
Trichospermae, 261.
Trichospermum, 262.
Trichostigma, 1091.
Trichovaselia, 338.
Triclisia, 58.
Tricomaria, 285.
Tricomariopsis, 285.
Tricuspidaria, 266, **270**.
Tridax, 803.
Trientalis, 862.
Trieste Sumach, 460.
Trifolieae, 503, 507, 509, 510.
Trifolium, 534.
Trigonachras, 430.
Trigonella, 534.
Trigonia, 145.
Trigoniaceae, 137, 142, 142–5, 284, 361.
Trigoniastrum, **144**, 145.
Trigonochlamys, 349.
Trigonopleura, 1235.
Trigonostemon, 1234, 1235.
Triguera, 978.
Trimenia, 1144.
Trimeria, 127.
Trinçomalee Wood, 261.
Trinia, **714**, 724.
Triodon, 775.
Triolena, 648.
Triomma, 349.
Triopteris, 285.
Triosteum, 758.
Triplaris, **1088**, 1100, 1101.
Triplochiton, **250**, 253.
Triplostegia, 781.
Tripteris, 803.
Tripterodendron, 430.
Tripterygioideae, 395.
Tripterygium, 397.
Triptilion, 803.
Tristania, 630.
Tristellateia, 285.
Tristemma, 648.
Tristicha, 1104.
Tristira, 430.
Tristiropsis, 430.
Triumfetta, 262.
Triumfetteae, 261.
Trivalvaria, 49.
Trochetia, 253.
Trochocarpa, **838**, 847.
Trochodendraceae, 28, 36, 39–42. [42.
Trochodendron, **14**, 28, 34, **40**,
Trochomeria, 691.
Trollius, 7.
Tropaeolaceae, 304–5.
Tropaeolum, **296**, 305.
Trophis, **1264**, 1270, 1271.
Trukia, 776.
Truxillo Coca, 275.
Trymalium, 413.
Trymatococcus, 1271.
Tryphostemma, 680.
Tsimatimia, 178.
Tuba Root, 530.
Tubercles, root, *see* Root nodules.
Tulasnea, 648.
Tulipiferin, 19.
Tulip Oak Wood, 253.
Tulipwood, 533.
Tung Oil, 1232.
Tupeia, 1194.
Tupelo Wood, 751.

Tupidanthus, 735.
Turkey Nuts, 1309.
Turnera, **672**, 674, **682.**
Turneraceae, 108, 669–74.
Turnips, 86.
Turpentine, Australian, 630.
Turpinia, **444**, 447.
Turraea, **334**, 358.
Turraeanthus, 358.
Tutcheria, 190.
Tydaea, 1002.
Tyleria, 338.
Tylophora, 924.
Tyloses, pitted, 56, 107, 216, 875, 929, 1037, 1135, 1275.
Tyloses, sclerotic, 56, 122, 135, 175, 270, 364, 457, 474, 552, 607, 645, 661, 875, 897, 909, 1037, 1135, 1151, 1313.
Tylosoids, 347.
Tylostemon, 1155.
Tynanthus, 1011.

Uapaca, 1234, 1235.
Ulex, 534.
Ullucus, 1086. [1289.
Ulmaceae, 34, 1269, 1271–8,
Ulmiform vessel pattern, *see* 'Vessels'.
Ulmus, **1274**, **1276**, 1278.
Umbelliferae, 129, 148, 712–24, 733, 734, 740.
Umbelliflorae, 734.
Umbellularia, **1150**, 1155.
Umbilicus, **570**, 581.
Uncaria, 775, 776.
Ungeria, 253.
Ungnadia, 430.
Unilaterally compound pitting, *see* 'Vessels'.
Unilaterally paratracheal parenchyma, *see* 'Parenchyma'.
Uninerves, 479.
Unona, 49.
Unonopsis, 49.
Upuna, 220.
Uragoga, **766**, 776.
Urandra, 376.
Uraria, 534.
Urbania, 1041.
Urbanodendron, 1155.
Urena, 233.
Ureneae, 225, 226, 229, 232.
Urera, 1229, **1250**, 1253.
Urereae, 1246, 1249.
Urophyllum, 775, 776.
Urospermum, **784**, 803.
Ursinea, 803.
Urtica, **1244**, **1248**, 1253.
Urticaceae, 1143, 1229, 1244–54, 1257, 1258, 1269, 1277, 1289.
Urticales, 34, 1119, 1229.
Urvillea, **424**, 430.
Usteria, 932.
Utricularia, 994.
Uvaria, 17, 49.
Uvariastrum, 49.
Uvariodendron, 49.

Vacciniaceae, 820–7, 827, 829, 835, 850.
Vaccinieae, 822.
Vaccinium, **824**, **826**, 827.
Vachellia, **482**, 487.
Vahea, 917.
Vahlia, 557.
Vaillantia, 775.
Valenzuelia, 430.
Valeriana, **778**, 779.
Valerianaceae, 777–80, 781.
Valerianella, 779.
Valerian Roots, 779.
Vallaris, 917.
Vallea, **264**, 266.
Vallesia, 917.
Vancouveria, 63.
Vandellia, 988.
Vangueria, 775, 776.
Vangueriopsis, **766**, 776.
Vanillosmopsis, 803.
Vantanea, 279.
Varronia, **946.**
Vascular tracheids, 44, 231, 259, 365, 410, 446, 459, 778, 877, 922, 1001, 1174, 1199, 1200, 1288.
Vaselia, 338.
Vasicentric parenchyma (in wood), xxiv.
Vasicentric tracheids (in wood), xlix, 1351.
Vasivaea, 262.
Vateria, **214**, 220.
Vatica, 220.
Vauquelinia, 549.
Vavaea, 358.
Veatchia, 461.
Vegetable Marrows, 691.
Vein islet number, 277, 315, 986, 987.
Veins, diagnostic features of, xvi.
Veins vertically transcurrent, xvi, 1334.
Veins with parenchymatous sheaths, 1335.
Vella, 87.
Velleia, 809.
Venidium, 803.
Ventilagineae, 406.
Ventilago, 413.
Venus's Fly-trap, 583.
Vepris, 316. [1041.
Verbascum, **980**, **982**, 988,
Verbena, **1034**, 1041.
Verbenaceae, 1030–41.
Verbena, Oil of, 1040.
Verbenoideae, 1031.
Verbesina, 804.
Vernonia, **790**, 803, 804.
Vernonieae, 783.
Veronica, **982**, 988, **1000.**
Verticordia, 630.
Vessels, absent, 27, 41, 44, 67, 70, 809, 1325, 1351.
— dendritic pattern, xlix, 1351.
— diagnostic features of, xxii, xlix.
— diameter, xxii, 1360.
— fibriform members, 13, 393, 678.
— in pith, 1021.
— in rays, 525.
— intervascular pitting, alternate, xliii.
— — minute, xlvi, xlvii.
— — opposite, xliii, xlv, 24, 31, 35, 47, 51, 107, 122, 187, 201, 209, 211, 229, 264, 278, 294, 327, 364, 371, 378, 384, 387, 417, 433, 437, 440, 446, 447, 457, 465, 474, 545, 571, 573, 576, 590, 591, 607, 608, 625, 633, 678, 703, 719, 731, 739, 750, 755, 825, 832, 838, 846, 889, 892, 1219, 1221, 1223, 1238, 1242, 1275, 1281, 1292, 1304, 1313, 1321.
— — scalariform, xliii, xlv, 24, 31, 35, 51, 107, 122, 173, 187, 194, 207, 209, 311, 327, 359, 364, 371, 384, 387, 417, 442, 563, 567, 571, 573, 576, 590, 605, 606, 607, 633, 645, 667, 678, 703, 731, 739, 750, 755, 825, 846, 889, 892, 1223, 1238, 1242.
— member length, xxiii, xlii, 1360.
— members fibriform, 13, 393, 678.
— members imperfect, 93, 313.
— number, xxii, 1361.
— origin of, xli.
— perforation plates, *see* 'Ephedroid', 'Foraminate', 'Reticulate', and 'Scalariform'.
— pits perforated, 951.
— radial or oblique pattern, 12, 15, 51, 61, 77, 93, 129, 168, 175, 180, 215, 275, 283, 289, 310, 321, 336, 345, 352, 363, 384, 407, 425, 455, 483, 493, 545, 552, 567, 625, 677, 697, 719, 768, 793, 846, 856, 867, 875, 883, 897, 909, 971, 1001, 1005, 1021, 1025, 1035, 1141, 1149, 1179, 1223, 1275, 1287, 1299, 1304, 1308, 1313, 1317.

Vessels, ring-porous, xlvi, xlvii, 1350.
— solitary, xlv.
— spirally thickened, xlvi, xlviii, 1349.
— tangential pattern, 56, 101, 129, 168, 229, 249, 283, 310, 321, 364, 371, 384, 483, 488, 519, 563, 570, 573, 608, 644, 678, 703, 719, 731, 755, 768, 793, 832, 846, 867, 929, 944, 951, 971, 1005, 1025, 1035, 1050, 1081, 1165, 1199, 1221, 1275, 1318.
— ulmiform pattern, 47, 61, 310, 407, 455, 731, 1275.
— unilaterally compound pitting, 18, 23, 31, 47, 122, 175, 201, 257, 264, 270, 283, 302, 311, 321, 329, 345, 359, 384, 398, 401, 409, 440, 495, 571, 605, 606, 607, 609, 1001, 1050, 1142, 1149, 1167, 1242, 1251, 1308, 1321.
— vestured pits, xlix, 1350.
Vestia, 978.
Vestured pits (in wood), xlix, 1350.
Viborgia, 534.
Viburnum, **750**, **754**, **756**, 758.
Vicia, **504**, **505**, 534.
Vicieae, 503, 507, 508, 509.
Victoria, 71, **72**.
Vigna, 534.
Villaria, 775.
Villarsia, 939.
Villebrunia, 1229, 1253.
Viminaria, 534.
Vinca, **904**, 917.
Vincetoxicum, **920**, 924.
Vinticena, 262.
Viola, **100**, 108.
Violaceae, 102–9, 126, 337, 1230.
Violaceae-Sauvagesieae, 108.
Virgilia, 534.
Virginia Creeper, 419.
Virginian Sarsaparilla, 734.
Virginian Snakeroot, 1119.
Virola, **1132**, 1138.
Viscainoa, 292.
Viscaria, 152, **154**.
Viscum, **1180**, **1192**, 1194.
Vismia, 169, **176**, 272.
Vismieae, 167.
Visnea, 190.
Vitaceae, 419.
Vitaceae, *see* Ampelidaceae, 413.
Vitex, **1034**, **1036**, 1041.
Vitis, **412**, **416**, 419.
Vitoideae, 419.
Viviania, 297.
Voacanga, **910**, 917.
Voandzeia, 534.
Vochysia, 142, **144**.
Vochysiaceae, 131, 137, 139–42, 142, 143, 145, 284, 361.
Vogelia, 857.
Volkensiophyton, 1023.
Vouacapoua, 534.
Vouapa, 501.
Vouarana, 430.
Voyria, 939.
Voyriella, 939.

Wahlenbergia, 816.
Waldsteinia, 549.
Wallacea, 338.
Wallaceodendron, 487.
Wallenia, 871.
Walnut wood, 1290.
Walnut wood, African, 357.
Walnut wood, East Indian, 486.
Walsura, **354**, 358.
Waltheria, 253.
Wangerinia, 156.
Warburgia, **106**, 111.
Warionia, 803.
Warscewiczia, 775, 776.
Washington Naval Orange, 314.
Water Chestnut, 667.
Water Lily, 71.
Water-melon, 691.
Water pores, *see* Hydathodes.
Wattle Bark, 486.
Wax glands, 1260.
Wax, Japan, 460.
Wax on leaf surface, 17, 26, 75, 81, 117, 149, 221, 431, 479, 540, 579, 621, 707, 709, 822, 829, 918, 1030, 1076, 1209.
Wax on stem surface, 676, 701, 808, 867.
Webera, 775, 776.
Weddellina, 1104.
Wedelia, 803, 804.
Weigeltia, 871.
Weihea, 611.
Weinmannia, **562**, 564, **570**.
Wendlandia, 775, 776.
Wendtia, 297.
Werckleа, 233.
West African Dika Nut, 325.
West Indian Boxwood, 127.
West Indian Locust, 500.
West Indian Satinwood, 314.
Westringia, 1053.
Wetria, 1235.
Whipplea, 577.
White Bryony, 691.
White Cedar, 1011.
White Oak, 1314, 1315.
Whitewood, 19.
Whitfieldia, **1020**, 1023.
Whortleberry, 825.
Wielandia, 1234.
Wigandia, 945.
Wightia, 988.
Wikstroemia, **1172**, 1178.
Wilbrandia, 691.
Wilcoxia, 705.
Willow, Cricket-Bat, 1320.
Willow wood, 1319.
Willughbeia, 917.
Wilsonia, 964.
Wimmeria, 397.
Winchia, 917.
'Window' leaves, 706, 709.
Winteraceae, 19, 24, 25, 25–30, 42, 43.
Winter's Bark, 29.
Wirtgenia, 840.
Wislizenia, 94.
Wissadula, 233.
Wistaria, 534.
Withania, 978.
Woad, 86.
Wood, diagnostic characters, xxi.
Wood flowers, 1194.
Wood, phylogenetic characters, xl.
Woodfordia, **650**, 654.
Wormia, 11, **20**.
Wormseed, 802.
— American, 1084.
Wormskioldia, 674.
Wormwood, 802.
Wrightia, 917.
Wulfenia, 988.

Xanthium, 803, 976.
Xanthoceras, 430, **438**.
Xanthochymus, 178.
Xanthophylleae, 133.
Xanthophyllum, **136**, 137, 138.
Xanthosia, **712**, 724.
Xanthostemon, 630.
Xeranthemum, 803.
Xerochlamys, 223.
Xeroplana, 1041.
Xerospermum, 430.
Ximenia, **360**, 366.
Xolisma, **828**, 836.
X-rays, influence of, on structure, 226.
Xylem, compound, 1343.
Xylem, divided, 1343.
Xylia, 487.
Xylocarpus, 358.
Xylochlaena, 223.
Xylomelum, 1168, 1169.
Xylopia, **48**, 49.
Xylosma, 127.
Xymalos, 1144.

Yagé, 284.
Yapon Tea, 385.
Yaupon Tea, 385.
Yellow Birch, 1305.
Yellowheart, Burma, 932.
Yellow Jasmine Root, 932.
Yellow Poplar Wood, 19.
Yellow Sassafras Wood, 1144.

Yemeri, 142.
Yerba Maté, 385.
Yercum, 923.
Yohimbe Bark, 774.
Yoroconte, 21.

Zahlbrucknera, 557.
Zaluzania, 803.
Zaluzianskya, 988.
Zanha, 430.
Zanonia, 691.
Zanthoriza, **2**, 7.
Zanthoxylum, 316.
Zataria, 1053.
Zea, 985.
Zebra Wood, 461, 886.
Zelkova, **1274**, 1278.
Zenobia, 836.
Zexmenia, 803.
Zeyheria, 1011.
Zeylanidium, 1104.
Zieria, 316.
Zilla, 87.
Zinnia, 803.
Zinowiewia, 397.
Ziricote Wood, 953.
Zizyphus, **408**, 413.
Zollernia, 501, 534.
Zollikoferia, **784**, 803.
Zollingeria, 430.
Zonanthus, 939.
Zornia, 534.
Zschokkea, 917.
Zuccagnia, **494**, 501.
Zuccarinia, 775, 776.
Zuelania, 127.
Zygocactus, **700**.
Zygogynum, 29.
Zygophyllaceae, 137, 142, 145, 284, 285–92, 329.
Zygophyllum, 292.

PRINTED IN GREAT BRITAIN
AT THE UNIVERSITY PRESS, OXFORD
BY CHARLES BATEY, PRINTER TO THE UNIVERSITY